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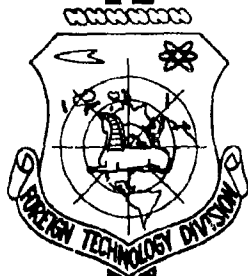
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TRANSLATION

ACUTE RADIATION INJURIES AND THEIR TREATMENT

By

I. M. Poltavets, F. F. Sinitsyna, et al.

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO

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I. M. Poltavets, F. F. Sinitsyna,
M. P. Filippov, M. P. Kolyada

OSTRYYE RADIATSIONNYYE PORAZHENIYA I IKH LECHENIYE

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This book describes methods of treating acute radiation injuries, the therapy of patients with radiation injuries, and the pathologoanatomical changes which occur in the body during this illness.

The classification and evacuation of casualties in a focus of mass injury and the organization of dosimetric monitoring in the establishments and institutions of the medical service of the GO are described, the latest data being taken into account.

This book is intended for physicians in all specialties and for students in advanced courses at medical institutes.

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INTRODUCTION

Since they first came into existence the Soviet government, the Communist Party, and the entire Soviet nation have struggled for peace.

China, the socialist countries, and all progressive individuals are included in the true struggle for peace.

These nations are filled with determination to uphold the cause of peace, which is so necessary for the most rapid building of a communist society.

The entire world knows the peaceful steps taken by the Soviet government.

The Soviet people are proud of their Motherland, which upholds peace throughout the world, and of their outstanding science and technology, which created the first artificial satellites of the earth and the first cosmic rockets.

The fact that the imperialist governments have atomic and thermonuclear weapons at their disposal obliges all Soviet citizens to be completely familiar with their properties and the measures for protecting against them.

The literature of the last few years has enabled many Soviet medical workers to become acquainted with the problems of radiation sickness.

However, the importance of the matter requires that all medical workers in the medical service of the GO study the problems of the classification and therapy of acute radiation injuries.

The authors' collective has set itself the task of assembling and

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systematizing the basic problems in the symptomatology, pathogenesis, and therapy of radiation injuries caused by external and internal ir-radiation.

Data published in the Soviet and foreign press (except Chapter 6) and the experience gained in practical training matters by the personnel of the establishments and institutions of the medical service of the GO served as the materials for this book.

In addition to problems of the symptomatology and therapy of acute radiation sickness and the characteristics of radioactive substances, combined injuries and radiation burns, this book describes the basic principles of the organization of dosimetric monitoring and the medical classification and evacuation of casualties (Chapters 5 and 6).

In editing the book we tried to abridge the material submitted as far as possible, in order to facilitate its study by the broad masses of medical workers. The authors consequently do not pretend to a complete exposition of the problems touched on.

If this book aids medical workers in studying the principles of the organization of medical security and the symptomatology, therapy, and classification of mass radiation injuries, the authors' collective will be rewarded for its modest labors.

The Editor

Chapter 1

CHARACTERISTICS OF INJURIES SUSTAINED IN ATOMIC EXPLOSIONS

Peculiarities of Atomic Explosions

The term atomic (nuclear) weapon is used to refer to those weapons whose action is based on the use of atomic (intranuclear) energy. We may distinguish two types of atomic weapons: explosive weapons and radiological warfare agents.

An atomic explosive weapon is based on the use of atomic energy released in large quantities as a result of reactions of an explosive character, i.e., at the instant of explosion. It is designed to destroy various targets and to injure the population.

These weapons now take the form of atomic and hydrogen bombs, projectiles, torpedoes, short- and long-range rockets, and self-propelled missiles.

The power of an atomic explosion is characterized by the TNT equivalent, i.e., the weight of TNT whose explosion releases an energy equal to that of the atomic explosion in question. Depending on the magnitude of the TNT equivalent, atomic bombs may be estimated as being equal to from several thousand to hundreds of thousands of tons of TNT.

The TNT equivalent of hydrogen bombs reaches millions of tons.

An atomic explosion is accompanied by the simultaneous action of a powerful shock wave, luminous radiation, and penetrating radiation, as well as by radioactive contamination of the vicinity of the explosion.

An atomic explosion can be carried out in the air above the earth

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(water), at the surface of the earth (water), or underground (under-
water). Atomic explosions are consequently referred to as atmospheric,
above-ground (over water), or underground (underwater). The point on
the surface of the earth above which an atmospheric explosion is car-
ried out is called the epicenter of the explosion.

A blindingly bright flash which illuminates an area for tens of
kilometers from the center of the explosion and is accompanied by a
loud noise resembling a powerful lightning discharge occurs at the in-
stant of an atomic explosion.

In an atmospheric explosion a fireball (a hemisphere in a surface
explosion) with a temperature of millions of degrees at the explosion
center is formed after the flash. The fireball shines like the sun for
2-3 seconds. The luminescence of the fireball is caused by the presence
of incandescent gases. Rapidly increasing in size, the fireball rises
and cools off, becoming a fluffy radioactive cloud. At the same time a
column of dust and smoke rises from the earth, giving the radioactive
cloud a mushroom-like shape. This cloud reaches a height of 10-12 km
after several minutes and is carried in the direction of the wind for
a considerable distance from the site of the explosion. Along the
cloud's path the large radioactive particles which were thrown aloft
fall to earth, contaminating the ground and objects below. When the
appropriate measures are not taken to protect humans and animals the
radioactive substances which fall in the vicinity are dangerous for a
definite time. The greatest contamination of the surrounding region
with radioactive substances occurs in surface explosions.

In an underwater explosion an enormous column of water is thrown
up into the air. This results in the formation of a mass of spattered
water which takes the form of a dense mist. A wave up to 50 m high de-
velops at the surface of the water, presenting a danger to surface

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ships and coastal installations.

Injurious Factors of an Atomic Explosion

The shock wave is the basic injurious factor of an atomic explosion. More than half of the total energy of the explosion is consumed in forming it. The shock wave of an atomic explosion is a region of compressed air under a pressure which reaches hundreds of thousands of atmospheres at the center of the explosion. Propagating at very high speed in all directions from this center, it can injure persons and destroy buildings. The greatest shock-wave destruction and injury is caused by an atmospheric explosion at an altitude of 600-700 m and occurs at a distance of 800-1500 m from the epicenter of the blast, depending on the size of the atomic bomb.

The shock wave can act on man in a two-fold fashion: directly and indirectly. Damage to internal organs and internal hemorrhaging may be observed in the first case; traumas and burns caused by so-called secondary projectiles (bricks, stones, and pieces of wood) formed as a result of the destruction of buildings and of fire occur in the second case. According to the data of foreign authors, up to 50% of the deaths in the atom bombing at Hiroshima were caused by the action of the shock wave.

The character of the injurious effect of the shock wave depends on the action of the overpressure and the distance of the people and buildings from the epicenter of the explosion, as well as on the TNT equivalent.

The extent to which unsheltered persons are injured by the action of the overpressure may be characterized by the following guideline data (Table 1).

The higher the TNT equivalent of the atomic or thermonuclear bomb, the lower will be the pressure necessary to inflict injuries (contu-

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TABLE 1

A Избыточное давление в кг/см²	B Травмы (вне укрытий)	
0,25	C	Легкие
0,4	D	Средней тяжести
0,6	E	Тяжелые
0,9	F	Смертельные

A) Overpressure, in kg/cm^2; B) traumas
(to unsheltered individuals); C) mild;
D) of moderate severity; E) serious; F)
lethal.

sions) on man. This is primarily due to the time for which the over-
pressure acts on the body. Depending on the distance from the center
(epicenter) of the blast, an enormous overpressure is generated at the
instant of explosion, reaching tens and hundreds of kilograms per
square centimeter.

The shock wave propagates in all directions from the center (epi-
center) of the blast, its injurious action decreasing as we move far-
ther from the center. One of the peculiarities of the shock wave is
its propagation rate. Within the effective radius of the shock wave
its front moves at a supersonic speed and reaches objects 1 km from
the blast site in 2 seconds, those 2 km away in 5 seconds, those 3 km
away in 8 seconds, and those 13 km away in 35 seconds (Fig. 1).
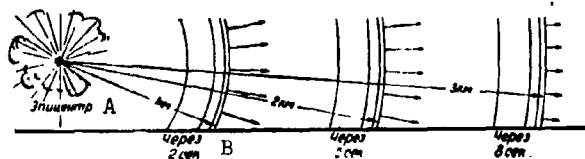
Fig. 1. Propagation rate of shock-wave
front. A) Epicenter; B) after 2 sec.

Protective structures (shelters) intended to safeguard the popu-
lace are of great importance. A shelter partially protects persons
from the shock wave and penetrating radiation and completely protects
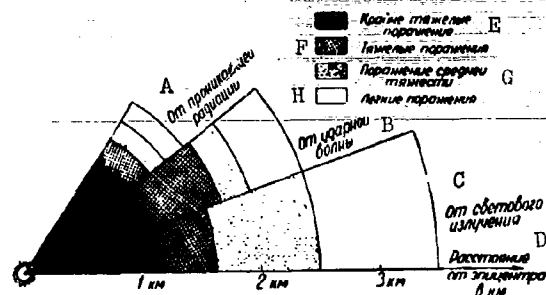
Fig. 2. Radii of zones of injury of luminous radiation, shock wave, and penetrating radiation for unprotected persons in atmospheric explosion of a medium-size atomic bomb (guideline data). A) From penetrating radiation; B) from shock wave; C) from luminous radiation; D) distance from epicenter, in km; E) extremely severe injuries; F) severe injuries; G) injuries of moderate severity; H) mild injuries.

them from luminous radiation.

While houses and other buildings on the surface are destroyed when the overpressure is approximately 0.3-0.35 kg/cm^2, a shelter completely withstands this pressure and can sustain one of up to 1-5 kg/cm^2 or more. Protective shelters consequently reduce the shock-wave injuries to the populace by a factor of 1.5-3.

The luminous radiation lasts for several seconds, approximately 1/3 of the energy of the atomic explosion being consumed in generating it. The injurious effect of the luminous radiation depends on the extent to which the body is heated and decreases as the distance from the epicenter of the blast increases, as a result of dissipation of the light. Despite the brevity of its action, the luminous radiation is capable of causing burns on exposed portions of the body and temporary blindness in unsheltered persons (Fig. 2).

The data in Table 2 characterize injuries as a function of the action of light pulses on unprotected body surfaces.

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TABLE 2

A Световой импульс в кал/см²			B Степень ожогов
C	**D**		
От 2 до	5		F Ожоги 1-й степени
от 5 до	10		G Ожоги 2-й степени
от 10 до	20		H Ожоги 3-й степени
E более 20			I Обугливание

A) Light pulse, in cal/cm^2; B) degree of
burns; C) from; D) to; E) more than; F)
1st-degree burns; G) 2nd-degree burns;
H) 3rd-degree burns; I) charring.

Depending on distance, the quantity of energy liberated as luminous radiation by an atomic explosion reaches tens and hundreds of calories per square centimeter. Charring, fires, and fusion of various objects, machines, and structures may consequently occur under the action of luminous radiation, particularly in an atmospheric atomic explosion.

The action of the luminous radiation is sharply reduced when fog, smoke, or dust are present in the atmosphere and during rain- and snowstorms. Any obstacle (a wall, armor, a roofed building, trees, etc.) capable of casting a shadow protects against the direct action of the light and eliminates or reduces burning.

Luminous radiation has no great injurious effect in an underground (underwater) blast.

Penetrating radiation acts at the instant of an atomic explosion and for a certain time after it, as a result of the deexcitation of the radioactive cloud. Penetrating radiation comprises γ-rays, neutrons, α- and β-particles, and x-rays. Considering their range, the γ-rays and neutron flux are the dangers to man. The basic sources of γ-rays and neutrons in an atomic explosion are the radioactive fission products of the nuclear-fuel atoms, which are found in the blast zone, and the radioactive cloud. The penetrating radiation produced in an atomic

explosion acts for fractions of a second (the neutron flux) and 10-12 seconds (the γ-radiation). Under the action of neutrons certain substances in the ground (especially in alkaline, sandy, and clay soils) and certain metals become radioactive. From 5 to 15% of the total number of deaths at Hiroshima and Nagasaki were due to the action of penetrating radiation.

The effects of radiation are considerably reduced by various types of shielding. Thus, for example, 14 cm of earth halves the radiation dose, 60 cm of concrete or 1 m of earth reduce it by a factor of 100, 40 cm of wood or 1 m of snow reduces it by a factor of 4, etc. The roofs and walls of sheltering buildings thus greatly attenuate the action of radiation. Penetrating radiation does not have a detrimental effect on various objects and machines, with the exception of optics and photographic materials. In addition to the simultaneous action of the aforementioned factors, radioactive contamination (pollution) occurs in the vicinity of an atomic explosion. Neutron irradiation can lead to the breakdown of dosimetric apparatus.

The radioactive substances which fall in a locality as the result of an atomic (thermonuclear) explosion may be the source of α- and β-particles and γ-rays. These radioactive substances present the greatest danger when they enter the body through the respiratory pathways, with food or water, or through wounds or burnt surfaces.

Alpha- and beta-particles have a low penetrating power, but exert a considerable injurious action on living tissue when they enter the organism; this is especially true of alpha-particles, which have a relatively high mass, energy, and charge.

A surface explosion causes the greatest contamination of the vicinity with radioactive substances. The radiation level at the blast site may reach 8000 r/hr one hour after an atom bomb with a TNT equiv-

alent of approximately 30-50 thousand tons is exploded and 900 r/hr
after 6 hours. The radiation level at a distance of 1-2 km reaches
0.03 r/hr after 6 hours. This level decreases rapidly as time goes on.

The size of the zone of contamination and the extent of the pollution depends chiefly on the character of the terrain and the power of the blast, as well as on the wind direction and velocity and other meteorological conditions.

In an atmospheric blast the basic mass of radioactive fission products rises with the cloud and does not cause dangerous contamination of the actual focus of injury. There may be intensive contamination in the central zone (see below) for 20-30 minutes after the explosion and beyond the focus of injury, in the area of fallout from the radioactive cloud. In this case we must take into account the fact that the larger the size of the atom bomb, the greater will be the area of contamination. The greatest degree of contamination does not always occur at the epicenter. This is due to the fact that the radioactive cloud produced by a high-power atmospheric blast rises to a great altitude and spreads in the direction of the wind, being carried over the focus of injury, occasionally for a considerable distance, and contaminating a large area with radioactive substances.

Radioactive substances which strike unprotected skin or the mucous membranes and are not removed in time may cause dermal injuries, while those which enter the organism may produce radiation sickness, just as penetrating radiation.

The literature contains a great deal of information on the injurious factors of atom bombs. We will now briefly acquaint the reader with the action of the injurious factors of hydrogen bombs.

According to the data of the United States Atomic Energy Commission on the hydrogen-bomb explosion on Bikini in March 1954, the fol-

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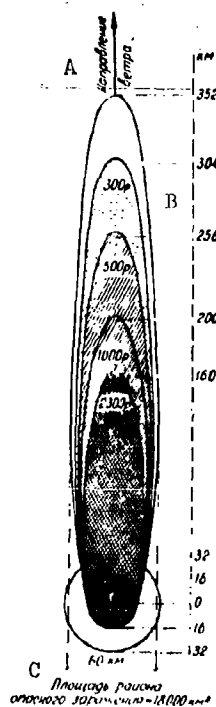
Fig. 3. Region contaminated by the products of the experimental nuclear explosion conducted by the USA on 1 March 1954. A) Wind direction; B) r; C) area of region of dangerous contamination – 18,000 km^2.

lowing facts are known. The diameter of the fireball produced by the explosion of a hydrogen bomb with a TNT equivalent of approximately 15 million tons reaches 6.5 km. The injurious factors of a hydrogen blast have a considerably greater effective radius and act approximately 10 times as long as those of an atomic explosion. The shock wave is the basic injurious factor. The radius of the zone of complete shock-wave destruction is 8 km; the radius of the zone of partial destruction is 32 km from the epicenter of the blast.

Luminous radiation causes 3rd-degree burns over a radius of approximately 30 km, 2nd-degree burns over a radius of 40 km, and 1st-degree burns over a radius of 50 km. The effective radius of the luminous radiation depends on atmospheric conditions and the altitude of the blast.

The penetrating radiation acts within 6-8 km of the epicenter at the instant of the explosion, i.e., in the zone of complete destruction, and is consequently of no practical importance.

A fourth injurious factor, residual radioactive contamination of the vicinity, is of greatly increased importance. The foreign press contains indications that the radioactive action of a hydrogen blast is the principal injurious factor. The total area of the contaminated region having radiation levels sufficient to cause severe injury or death to unprotected persons reaches 18,000 km^2 after hydrogen-bomb

explosions (Fig. 3).

Contamination causing high radiation levels is produced over a radius of 15-30 km from the epicenter as a result of the fallout of large masses of radioactive dust. As a result of the fallout of radioactive dust the radioactive track in the windward direction has a length of several hundreds of kilometers and a width of 60-90 km or more. According to the data in the literature, the fallout of radioactive dust at a distance of 250 km from the epicenter of the blast begins 8 hours after the explosion and continues for several hours (a mean wind velocity of 30 km/hr being assumed). If an individual remains in the region of the radioactive track for 36 hours, he receives a total external γ-radiation dose of the following magnitude:

a) at a distance of 160 km from the epicenter — 2300 r;

b) at a distance of 200 km from the epicenter — 1000 r;

c) at a distance of 256 km from the epicenter — 500 r;

d) at a distance of 304 km from the epicenter — 300 r;

e) at a distance of 352 km from the epicenter — 67 r.

The total irradiation dose will increase if the individual remains in the contaminated area for more than 36 hours.

Zones of the Atomic Focus of Injury

The term atomic focus of injury refers to that region over which the action of a given factor or the sum of all factors of an atomic explosion extends and causes destruction and casualties.

It is customary to divide the focus into zones in accordance with the extent of the action of the factors of the blast, i.e., into the sections of the locality (destroyed city) in which the destruction and casualties have approximately the same character.

The central zone has a radius of up to 400 meters from the epicenter of the blast.

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Note: The data for all zones were taken from calculations for the explosion of an arbitrary atom bomb with a TNT equivalent of 20 thousand tons.

This region encompasses the maximum destructive and injurious action of all the factors of an atomic or thermonuclear weapon. Complete destruction of all surface buildings, no matter what their strength, occurs in this zone. With the exception of shelters, which are of special strength, destruction of subterranean installations is possible. The overpressure in this zone may reach several tens or hundreds of kg/cm^2, while the luminous radiation may be expressed in terms of tens of calories per cm^2.

The zone of complete destruction extends approximately 800 m from the epicenter. Buildings of all types, including those of reinforced concrete, are completely destroyed in this zone. Destruction of shelters, except those of high strength, is possible. The overpressure may reach 2 kg/cm^2 or more. Both of the aforementioned zones may be characterized as regions of complete conflagration. The number of untreatable casualties among the populace in these zones may be very high, depending on the percentage of persons which take refuge in high-strength shelters. Many casualties receive severe combined injuries which shortly lead to death. It must be taken into account that it is difficult for the organizations of the local GO to enter these zones soon after an atomic explosion.

The zone of great (intensive) destruction, which extends for approximately 1600 m from the epicenter, is characterized by complete destruction of multistory buildings and massive destruction of single-story structures. The shock wave creates an overpressure as high as 2 kg/cm^2 in this zone. Radiation in the form of large light pulses (approximately 10 cal/cm^2) also acts here. In addition to intensive de-

struction of all types of surface buildings and damage to the majority of shelters; this zone is characterized by continuous and isolated foci of conflagration and a considerable radiation effect. A large number of casualties with severe combined injuries urgently requiring medical aid is to be expected in the zone of massive damage. Depending on the radiation level, the personnel of the medical, fire-control, emergency engineering, and other services of the GO can begin urgent emergency rescue work, primarily the rescue of casualties.

The zone of moderate destruction, which extends approximately 2600 m from the epicenter, is characterized by moderate destruction of buildings and installations and isolated fires. The overpressure created by the shock wave drops sharply here, to 0.2 kg/cm^2, but the direct action of the shock wave on unprotected persons is not to be forgotten. Light pulses (ranging from 5 to 10 cal/cm^2) still have a considerable effect. Penetrating radiation is of no practical importance. The casualties (which may be considerable) will consequently sustain injuries which are severe or moderately severe and chiefly combined in character, urgently necessitating the rendering of immediate medical aid. It must be assumed that it will be possible for many organizations of the GO (public-health forces, the OPM, the fire departments, the emergency rescue squads, etc.) to begin rescue work in this zone and those beyond it within a few hours after the explosion. Protected medical aid stations, shelters, and some city and regional hospitals will be completely spared in this region.

The zone of little (light) destruction, which extends up to 4000 m from the epicenter, is characterized by a considerable reduction in the effects of the injurious factors of the atomic explosion. The overpressure decreases to tenths of a kg/cm^2 and the light pulses do not exceed 4 cal/cm^2. Here all of the therapeutic-prophylactic institutions

of the city will be spared and will be able to execute the tasks confronting them in rendering aid to the victims, carrying out public-health work, etc. In this zone and beyond, it will be completely possible for the medical, engineering-technical, and emergency rescue services of the GO to carry out all types of activities (when necessary). The access routes (roads) for automobile traffic will be completely spared, so that public health traffic, just as that for other activities, will be able to evacuate casualties freely or bring the necessary materials to them.

It is important to note that the city transportation system (trolleys and trolley-buses) can be maintained here and should be completely converted for evacuating casualties and bringing in the necessary supplies.

The buildings which are spared (both public and residential) may serve as the nearest points for first-stage accommodation of untransportable casualties after they are rendered emergency medical aid at the OPM.

The casualties will basically have sustained moderately severe and mild injuries combined with 1st- and 2nd-degree burns resulting primarily from the indirect action of the shock wave and from secondary fires.

The zone of partial (random) destruction extends to 10,000 m from the epicenter. This zone is characterized by partial destruction of buildings; window sashes, roofs, isolated ceilings, door frames, architectural ornaments, etc. are damaged.

The shock wave and luminous radiation do not directly affect unprotected persons. The rather small number of casualties sustain mild injuries. The therapeutic-prophylactic institutions in this zone are all spared and can accept and render the necessary medical aid to vic-

tims.

Characteristics of Casualties and Injuries Resulting from an Atomic Explosion

The character of the injuries caused by an atomic weapon and the number of victims are determined from specific data for each inhabited locality. The basic factors which determine the number and character of injuries are the type of atomic weapon, the size of the atom bombs, the manner in which the bombs are used, the population density and character of the construction in the inhabited locality, the existence of shelters or temporary refuges and their strength, the extent to which the populace has been trained in atomic defense, meteorological data, the topography of the area, etc.

As is well known, the first atomic bombs were dropped by the Americans on Japanese cities in August 1945. A great many works devoted to the action of atomic weapons have appeared in recent years. It must be noted that the casualty statistics of various authors are very contradictory. On the basis of a generalization and analysis of the data of foreign and Soviet authors, we may conclude that the total number of casualties from an atomic bombing may vary from 30 to 60% of the total population of a city, depending on the aforementioned conditions.

Of the total number of casualties among the populace, 1/3 (30-35%) may be beyond help, while 2/3 (65-70%) are treatable.

The severity of the injuries sustained by treatable casualties may be classified as follows: mild – up to 40%, moderately severe – up to 30%, and severe and very severe – up to 30%.

It may be seen from these rough data that the majority of the injuries (60%) may be regarded as severe and moderately severe and less than half of all treatable casualties (40%) will have mild injuries.

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This constitutes one of the peculiarities of the injurious action of atomic weapons in contrast to "conventional" means of destruction.

The total number of treatable casualties may be subdivided in accordance with the character of their injuries as follows: a) traumas — 20-30%; b) burns — 20-25%; c) penetrating radiation — 15-20%; d) combined injuries — 25-45%.

The aggregate of treatable casualties may comprise: traumas alone and in combination — 55%; burns alone and in combination — 55%; radiation alone and in combination — 50%.

The make-up of a simultaneously admitted group of casualties of an atomic weapon is consequently characterized by the massiveness and combined character of their injuries.

The statistical data briefly given above characterize the atomic focus of injury and the possible casualties, as well as the conditions which may develop as a result of an atomic attack; these latter must be taken into account by the medical service of the GO. Starting with arrangements specifically made for this purpose, the administrative agencies of this service (staff) must handle the supervision and maneuvering of all available forces and facilities, bringing all measures into compliance with the time factor. It would not be erroneous to state that this factor is the basis of the work of two services of the GO, the medical and fire-control services.

In the broad sense, the organization and tactics of the medical service of the GO must be taken to include the study of the form and methods of the most effective use of public health facilities and forces in eliminating the sanitary aftereffects of an air attack.

In eliminating the sanitary aftereffects in foci of mass injury it is necessary to ensure the most flexible and yet firmest administration of the forces and facilities of all branches of the medical ser-

Nuclear Radiations and the Units in which They Are Measured

The term radioactivity refers to the ability of a substance to emit rays spontaneously. We may distinguish three types of radioactive radiation: alpha (α) radiation, beta (β) radiation, and gamma (γ) radiation. Intensive neutron fluxes occur in atomic-bomb explosions and in nuclear reactors.

Alpha-particles are a stream of helium nuclei. They have a double positive charge and an atomic mass of 4. Flying out of the nucleus of an atom, an α-particle has a high energy (up to 10 million electron volts) and causes a high ionization density in the surrounding medium. Alpha-particles traverse a path of no more than 10 cm in air, being restrained by a 0.1 mm thickness of paper or by the horny layer of the epidermis. Radioactive substances which emit α-rays do not cause skin burns, but can damage the mucous membranes. They are most dangerous when they enter the body.

Beta-particles are a stream of electrons or positrons which travel at nearly the speed of light. The ionization density of tissue is considerably less under the action of β-particles than under that of α-particles. The former traverse a path of up to 15 m in air and penetrate to a depth of up to 1 cm in living tissues. Beta-radiating radioactive substances are dangerous when irradiation is external, but especially so when they enter the organism.

Gamma-rays are electromagnetic waves which are similar to x-rays but have a shorter wavelength. These rays are characterized by an extremely great penetrating power, acting over distances of hundreds of meters. A layer of 5 cm of lead, 30 cm of concrete, or 60-80 cm of earth must be placed in the path of the rays in order to attenuate γ-radiation by 90%. In an atomic explosion γ-rays are most dangerous on

Neutrons are uncharged particles. They do not cause ionization by themselves. The mass of a neutron is approximately equal to that of a proton. More than 99% of the neutrons are produced during the atomic explosion itself. These are prompt neutrons, while the remainder are delayed neutrons. The latter are produced by the fission products of uranium or plutonium 0.1 second after the explosion. The neutrons have an effective radius of up to 900 m. They have a high penetrating power and can pass through lead and other shielding. Neutron irradiation causes induced radiation in the bomb casing, the soil, various structures and objects, and the living organism.

Radioactive isotopes of sodium, phosphorus, potassium, calcium, etc., are produced in living organisms on neutron irradiation.

All radioactive radiations produce ionization on passing through matter; positively and negatively charged ions are formed from neutral atoms and molecules. The dosage unit for γ-rays is called the roentgen. One roentgen (r) is that dose of γ-rays which forms $2.083 \cdot 10^9$ ion pairs in 1 cm^3 of dry air under normal atmospheric pressure at a temperature of $0^\circ C$. A thousandth of a roentgen is called a milliroentgen and a millionth is called a microroentgen. The dose rate is the dose received by the surrounding medium per unit time. It is measured in roentgen-minutes, roentgen-seconds, etc. The permissible or tolerance dose for systematic irradiation is computed at 0.05 roentgen per day or 0.3 roentgen per week. This problem is now being reconsidered with a view to reducing the maximum permissible dose to 0.1 roentgen per week. An energy equal to 33 electron volts is necessary to form 1 ion pair in air and the energy absorbed per cm^3 of air at a dose of 1 roentgen is 0.11 erg. The energy absorbed in one gram of living tissue amounts to 83.8 ergs. This quantity of energy (83.8 ergs) absorbed in

one gram of tissue under the action of any type of ionizing radiation
constitutes the roentgen equivalent physical (REP). Doses of α- and β-
rays are measured in roentgen-equivalents-physical. This is that quan-
tity of α- and β-rays which ionize $2.083 \cdot 10^9$ ion pairs per cm^3 of air.

When they pass through the tissues of the body radioactive radia-
tions have a definite biological effect which increases with the ion-
ization density. The term ionization density or specific ionization
refers to the number of ion pairs which is formed by a given type of
radiation per micron of free path. The greatest ionization density is
produced by α-particles; neutrons and β-particles generate a lower
ionization density and that produced by γ-radiation and x-rays is
still less.

TABLE 4

Biological Effectiveness of Various
Types of Radiation

A Виды излучений	1 фэр соответ-ствует B	1 бэр соответ-ствует C
D Бета-частицы и гамма-лучи	1 бэр H	1 фэр I
E Альфа-частицы и протоны	10 .	0,1 .
F Тепловые нейтроны	5 .	0,2 .
G Быстрые нейтроны (40 Мэв)	10 .	0,1 .

A) Types of radiation; B) 1 REP corres-
ponds to; C) 1 REB corresponds to; D) β-
particles and γ-rays; E) α-particles and
protons; F) thermal neutrons; G) fast
neutrons (40 Mev); H) REB; I) REP.

The roentgen equivalent biological (REB) is that dose of ionizing
radiation of any type which causes the same biological effect in liv-
ing tissues as a dose of 1 roentgen of γ- and x-rays. Table 4 shows
the relationship between the REP and REB for different radiations
(N.G. Gusev).

The degree of radioactive contamination is characterized by the
quantity of radioactive substances contained on a unit surface or in a
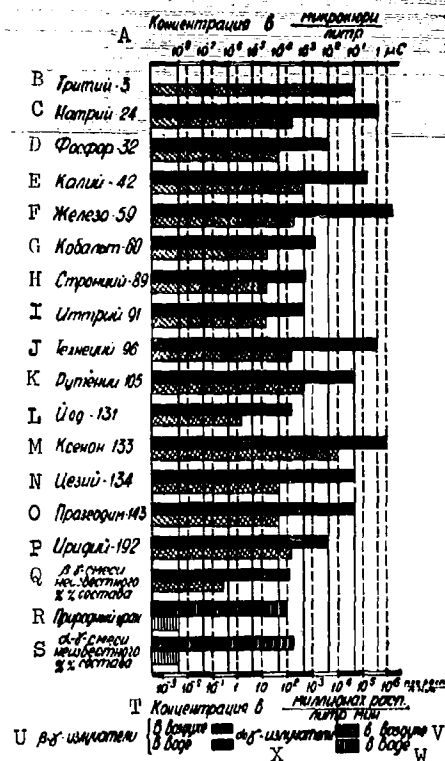
Fig. 4. Maximum permissible concentrations of certain radioactive isotopes in water and in the air of work areas (according to the sanitary-hygienic norms adopted in the USSR). A) Concentration in μC/liter; B) tritium; C) sodium; D) phosphorus; E) potassium; F) iron; G) cobalt; H) strontium; I) yttrium; J) technetium; K) ruthenium; L) iodine; M) xenon; N) cesium; O) praseodymium; P) iridium; Q) β-γ-mixture of unknown percentage composition; R) natural uranium; S) α-γ-mixture of unknown percentage composition; T) concentration in million decays/liter-min; U) β-, γ-radiators; V) in air; W) in water; X) α-, γ-radiators.

unit volume (weight) of the contaminated object.

The extent of the radioactive contamination of an area is expressed in curies per m^2 (curies/m^2) or as the number of decays of radioactive atoms per m^2 per unit time.

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The term radiation level customarily refers to the dose rate created at   height of 1 m above the surface of a contaminated area. The radiation level is expressed in roentgens per hour (r/hr). There is a definite relationship between the degree of radioactive contamination expressed in curies/m^2 and the radiation level. When the radioactive contamination of a surface is 1 curie/m^2 the radiation level is approximately 1 r/hr.

The extent of the radioactive contamination of the air is characterized by the concentration of radioactive substances in the air and is measured as the number of atoms decayed per minute per liter (min/liter).

The degree of radioactive contamination of water and liquid nutrients is measured as the number of atoms decayed per minute per cm^3 (min/cm^3), while that of solid nutrients is measured as the number of atoms decayed per minute per gram (min/g).

The maximum permissible content of β-active substances in water, air, and food products is characterized by the following data (according to the norms adopted in the USSR):

a) cotton protective clothing, gloves, equipment, and work shoes — up to 5 thousand decays per min in an area of 150 cm^2;

b) plastic-film protective clothing — up to 10,000 decays per min in an area of 150 cm^2.

Figure 4 shows the maximum permissible concentrations of certain radioactive isotopes in water and in the air of work areas.

Manu-
script
Page   [List of Transliterated Symbols]
No.

1   = GO = grazhdanskaya oborona = civil defense

Chapter 2

RADIOACTIVE SUBSTANCES

General Characteristics

When atomic weapons are used, injuries caused by radioactive substances may occur:

1. As a result of the action of radioactive substances – the products of an atomic explosion.

2. As a result of the action of radiological warfare agents.

Atomic explosions result in the formation of: firstly, radioactive fragments of uranium or plutonium; secondly, radioactive isotopes from the material of the bomb casing, in the soil, in sea water, and in various objects and structures as a result of radiation induced by the action of neutron fluxes; thirdly, dust from that portion of the uranium or plutonium which does not participate in the chain reaction, this diffusing into the air.

In the first case approximately 200 radioactive isotopes of 33 chemical elements are formed, ranging from $zinc^{30}$ to $samarium^{62}$. All of these isotopes are β- or β-γ-active. After the explosion they precipitate into a dust which rises from the earth. This dust contaminates the air and, settling slowly, the locality of the blast. Radioactive contamination of the environment by atomic explosions occurs primarily as a result of uranium or plutonium fragments. These present a greater danger to man than the radioactive substances which are the products of induced radiation or the residue of the uranium and plutonium. The activity of the uranium fragments reaches 10^5 curies for each thousand

tons of TNT to which the power of the blast is equal. Their half-lives range from fractions of a second to many years.

The most important of the radioactive fragments are those of strontium, yttrium, zirconium, technetium, ruthenium, tellurium, iodine, xenon, cesium, barium, cerium, praseodymium, neodymium, and promethium. The half-lives of these most dangerous isotopes vary from several days to tens of years. The most dangerous of the uranium (plutonium) fragments during the first 30 days are those of iodine isotopes (iodine^{131} etc.), but those of strontium, barium, yttrium, and others later take their place.

The second case involves the formation of products of induced radiation: radioactive isotopes of iron, zinc, etc., in the bomb casing; radioactive isotopes of sodium, potassium, aluminum, silicon, manganese, iron, etc., in the soil; radioactive isotopes of sodium, calcium, magnesium, chlorine, etc., in sea water. All of the products of induced radiation are β- or β-γ-active. The greatest quantity of radioactive induced-radiation products is formed in thermonuclear explosions.

In the third case that portion of the atomic charge — uranium or plutonium — which does not enter into the chain reaction diffuses into the air. An atomic explosion occurs almost instantaneously, within a millionth of a second. As a result of the extremely high temperature, which reaches tens of millions of degrees, a portion of the atomic charge is vaporized together with the bomb casing and scatters into the surrounding medium in a gaseous state, not being able to participate in the chain reaction. These products are α-active and are of no material importance in contaminating the environment because of their low activity.

Summarizing the above-described ways in which radioactive sub-

stances are formed during atomic explosions, we may make the following comparisons:

a) uranium or plutonium fragments produce the basic mass of radio-active substances in atomic explosions, generating 99% or more of the total radioactivity;

b) induced-radiation products are of secondary importance, yielding 1% of the total radioactivity;

c) the uranium or plutonium residues which do not participate in the chain reaction and diffuse into the air are of almost no importance.

Radioactive contamination of the vicinity of the blast depends on:

a) the size of the atomic bomb;

b) the character of the explosion (atmospheric, surface, underground, or underwater in salt water);

c) the meteorological conditions.

All other conditions being identical, the maximum contamination of the blast area occurs in surface and underground explosions.

Contamination of the blast vicinity is not particularly substantial in atmospheric explosions. The radioactive uranium fragments remain in the fireball after the explosion and rise to the edge of the stratosphere with the incandescent gases. They then spread over vast expanses of the earth in the direction of the wind, not creating any material contamination of the immediate vicinity of the blast. Contamination of the blast area itself will be observed over a short distance from the epicenter for several hours after an atmospheric explosion. In such cases radioactive contamination of the blast vicinity is caused solely by the development of induced radiation in the soil (Fig. 5).

Contamination of the blast vicinity reaches its maximum in surface explosions. This contamination develops as a result of the local
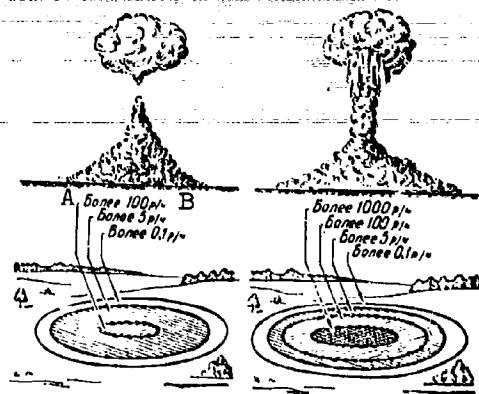
Fig. 5. Comparison of contamination
of the vicinity by atmospheric and
surface explosions. A) More than;
B) r/hr.

settling of radioactive uranium fragments and induced radiation in the
soil. A large quantity of dust is drawn up into the area of the fire-
ball in surface explosions. The uranium fragments are adsorbed on the
dust. The latter, which has become radioactive, falls on the blast re-
gion and along the path of the cloud, forming a so-called radioactive
track along the earth's surface.

In surface explosions the contamination of the blast vicinity
around the epicenter has a radius approximately 2-3 times greater than
in atmospheric explosions, while the radiation level is several hun-
dreds or thousands of times higher.

Meteorological conditions (wind, rain, snow) have a great effect
on the degree of contamination of the blast vicinity with radioactive
substances.

The greatest contamination of the blast vicinity develops when
hydrogen-uranium bombs (with an outer casing of uranium^{238}) are ex-
ploded. In such bombs natural uranium^{238} becomes fissile uranium under
the action of the high-energy neutrons formed during the igniting hy-
drogen blast, i.e., participate in the chain reaction.

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When a hydrogen-uranium bomb is exploded up to 90% of the blast
energy is created by the fission of uranium^{238}; in this case the quan-
tity of radioactive uranium fragments may be 1000 times greater than
that produced in the explosion of a normal atom bomb with a TNT equiva-
lent of 20,000 tons.

According to the data available, the area of dangerous contamina-
tion reaches 18,000 km^2 or more, i.e., a region 300 × 60 km in size,
when a hydrogen-uranium bomb with a TNT equivalent of 15-20 million
tons is exploded.

The term radiological warfare agents refers to high-toxicity
radioactive substances which the belligerants can use for military
purposes (to contaminate a locality and injure troops, the populace,
and animals). In order to produce radiological warfare agents (RWA)
special substances are irradiated with neutrons or the radioactive
wastes of atomic piles are used. RWA act on man through their radioac-
tive radiations.

Radiological warfare agents may be used in the solid, liquid, and
gaseous states. They can be scattered from aircraft or air bombs, ar-
tillery shells, and rockets can be equipped with them; RWA can be used
in the form of mists and fumes.

According to data in the foreign press, we must expect the use of
β- and γ-active substances with medium half-lives (several days to
several years) to contaminate the air as the first stage in such war-
fare.

The degree of contamination of a locality in which RWA are used
may remain dangerous for man for a longer or shorter period of time,
depending on the half-life of the substance used.

RWA may be used both in pure form and in various carriers. These
carriers can in turn be neutral or chemical warfare agents and may be

in the form of powders or liquids. The less carrier there is and the finer its aggregate state, the higher will be the toxicity of the mixture.

We will use the term radioactive substances below, understanding it to mean both the radioactive products of an atomic explosion and radiological warfare agents.

The basic characteristics of the action of radioactive substances are as follows:

1. Physical and tactical characteristics:

a) contaminate the entire environment in which man lives and acts;

b) are capable of injuring persons in shelters, entering them with contaminated air and on contaminated objects;

c) are capable of simultaneously contaminating a large area containing a great many persons. In the American view, RWA are strategic weapons.

2. Toxic characteristics:

a) are a source of ionizing radiation and consequently dangerous both when they enter the body and on external irradiation. These are radiotoxic poisons, which distinguishes them from CWA, which are chemical poisons;

b) are extremely toxic in negligibly small quantities by weight, their biologically active amounts being extremely low;

c) radioactive substances cannot be neutralized by either chemical or thermal treatment and the only way to protect against them is mechanical removal (deactivation);

d) have a prolonged action, depending on their half-lives, distribution, and the place where they accumulate in the body;

e) are detectable only with special dosimetric instruments; they produce no stimulation when they come into contact with man and are

not distinguished by a specific outward appearance, taste, or odor. Man cannot detect radioactive substances with his sense organs.

The severity and character of the injuries caused by radioactive substances depend on a number of factors:

a) the isotopic composition of the mixture (on which the character of its radiation depends), the energy of its radiation, and its half-life, chemical composition, and physical state;

b) the degree of contamination of the locality and the air;

c) the time for which they act;

d) meteorological conditions and the character of the terrain;

e) the condition of the organism;

f) the ways in which they enter the body, the character of their distribution within it, and the ways in which they are excreted;

g) the existence of protective facilities and the knowledge of how to use them.

The toxicity and distribution in the body of radioactive isotopes depends on their physicochemical and physical properties (Zakutinskiy). The toxicity of radioactive substances depends particularly on their half-lives.

The term half-life refers to that time in which half of the atoms of a given radioactive substance decay. Thus, the half-life of uranium is 4.5 billion years, that of radium is approximately 2000 years, that of carbon 5000 years, that of iodine 8 days, that of radon 3.8 days, etc. When taken in a toxic dose, all radioactive substances are dangerous for a period equal to 6 half-lives.

As is well known, radioactivity is the ability of a substance to emit α- and β-particles and γ-rays spontaneously. The unit of radioactivity is customarily taken as the curie; this unit is that quantity of any radioactive substance in which there are 37 billion ($3.7 \cdot 10^{10}$)

decays per second. A thousandth of a curie is called a millicurie and a millionth a microcurie. The toxicity of a radioactive substance depends on the type of radiation which it emits. Alpha-active substances are more toxic than beta-active substances when they enter the body, while the latter are more toxic than gamma-active substances. Beta-gamma-active substances cause the greatest changes when they strike the skin and visible mucosa. Mixing different radioactive substances results in an increase in toxicity. Certain radioactive substances have a considerably greater biological effect than the most powerful chemical poisons. Thus, while 2-3 micrograms of botulin is considered a lethal dose, 0.01 microgram of radioactive phosphorus, P^{32}, entering the organism and being deposited in the bones causes irradiation in a lethal dose of several hundreds of roentgens (Zheno).

The chemical composition of a radioactive substance determines its action on the organism (entry, distribution in the body, and excretion). No matter what their mode of entry, soluble radioactive substances penetrate into the body in larger quantities than insoluble substances. Radioactive substances which contaminate the air in the form of fumes or mists are most dangerous. All other conditions being identical, the severity of an injury caused by a radioactive substance is directly proportional to the degree to which the environment is contaminated and the time for which the substance acts.

Meteorological conditions affect the extent of contamination of the air and the blast vicinity. Rain- and snowstorms cleanse the air of radioactive dust (aerosols), but this increases the contamination of the surface of the ground. In dry weather the wind raises dust from the earth and greatly increases the contamination of the air in regions of radioactive pollution. Contamination with radioactive substances is less in open sections of the blast vicinity (fields with no

substantial grass cover and plazas or wide-paved streets in cities).
Conversely, buildings, fences, bushes, etc., will be subject to the
greatest radioactive contamination (settling of radioactive dust). The
condition of the organism has a material influence on the extent of
injury by radioactive substances. When the minute respiratory volume
is increased, as occurs under physical stress, the quantity of radio-
active dust which enters the respiratory pathways with the inhaled air
increases sharply. When ingested with food and water by hungry, thirsty,
or excited persons, radioactive substances may be absorbed from the
gastrointestinal tract into the blood in considerably larger quanti-
ties than under ordinary conditions (the increase amounting to a fac-
tor of 2-3-5).

TABLE 5

A Изотоп	B Токсичность по сравнению с радием	Допустимый уровень в организме человека (микро-кюри на весь организм) C
D 1. Стронций-90	0,1	1,0
E 2. Радий-206	1	0,1
F 3. Плутоний-239	2,5	0,004

A) Isotope; B) toxicity with respect to
radium; C) permissible level in the human
body (μC in entire body); D) strontium;
E) radium; F) plutonium.

Table 5 shows the relative toxicity of certain radioactive sub-
stances with respect to radium (V. I. Feoktistov).

Ways in which Radioactive Substances Penetrate into the Body

Radioactive substances can enter the body through the respiratory
pathways, the gastrointestinal tract, the skin and visible mucosa,
wounds and burns, and, finally, intramuscularly, intravenously, and
subcutaneously (in experiments).

Radioactive substances enter the lungs with inhaled air, this
mode of penetration being the most dangerous in practice. Gases and

soluble substances pass through the vast area (80 to 120 m^2) of the alveolar surface of the lungs into the blood, causing a general affection. There may occasionally be no changes in the respiratory pathways themselves in such cases.

Insoluble radioactive substances, which enter the respiratory pathways in the form of dust and aerosols, may be trapped in the mucosa and subjected to phagocytosis. In such cases radioactivity may be detected in the tissues of the respiratory pathways several months after contamination. Gaseous radioactive substances (radon, xenon, thoron, krypton, etc.) pass most easily and rapidly through the respiratory pathways. Yttrium^{91}, lanthanum^{140}, praseodymium^{143}, zirconium^{95}, and other isotopes are absorbed well through the walls of the alveoli. Isotopes such as radium^{226}, polonium^{210}, uranium^{238}, etc., are absorbed poorly. On the other hand, soluble salts of these chemical elements (uranyl nitrate, uranium hexafluoride) are absorbed well. In contrast to aerosols, radioactive dust is retained in the upper respiratory passages to a considerable extent.

Radioactive substances in carriers are retained in the upper respiratory passages more easily as their particle size increases. Radioactive fumes and mists are the most dangerous, since they penetrate deeply into the respiratory pathways, reaching the alveoli.

Radioactive substances can be ingested with contaminated food and water, by swallowing dust, with the saliva and mucus from the nasopharynx, while smoking, and from contaminated hands. The absorption of radioactive substances increases on an empty stomach. The most important factor governing absorbability is solubility; the higher the solubility of the substance, the greater the percentage of it absorbed. Iodine^{131}, cesium^{137} (100%), tellurium^{127} (25%), and strontium^{90} (up to 80%) are examples of isotopes which are absorbed well. Cerium^{144},

ruthenium[106], etc., are poorly absorbed (up to 0.05%). When radioactive dust is inhaled up to 30% of the total quantity of radioactive substances entering the respiratory organs passes through them into the blood; up to 12-15% of the quantity of radioactive substances ingested with water and food is absorbed.

When ingested, radioactive substances remain in the stomach for 0.5-2 hours and may then be detected in the intestine in decreasing quantity for 3-5 days. When radioactive substances contaminate wounds and burns they pass immediately into the blood, but the majority of them, being insoluble in the body fluids, remain in the tissues of the wound (burn).

The toxic effect of a radioactive substance depends on the manner in which it enters the body. Passage of radioactive substances directly into the blood through wounds and burns and by intravenous injection is the most dangerous. Penetration of radioactive substances through the respiratory organs is also extremely dangerous.

The action of such substances is somewhat mitigated when they enter through the gastrointestinal tract. For example, the toxicity of uranyl nitrate is 200 times less when it enters through the gastrointestinal tract than when it is administered intravenously.

It must be noted that radioactive substances are cumulative poisons. V.V. Kholin has shown that both physical and physiological cumulation are possible. Repeated intake of a radioactive substance in concentrations considerably below ordinary toxic levels may result in illness. This increases the danger of chronic exposure to small doses of radioactive substances.

Distribution of Radioactive Substances in the Body

No matter what their mode of entry, radioactive substances are found to have a specific selective distribution in the body which de-

pends on their chemical properties. The artificial radioactive iso-
topes are distributed in the body in the same fashion as the corres-
ponding stable isotopes. Thus, radioactive iodine is deposited in the
thyroid gland and phosphorus, strontium, barium, and yttrium in the
bones. V.V. Kholin has proposed that radioactive substances be classi-
fied into three basic groups in accordance with the character of their
deposition in various tissues:

1. Radioactive substances distributed predominantly in the bones
(radium^{226}, strontium^{89}, strontium^{90}, yttrium^{91}, phosphorus^{32}, cal-
cium^{15}, plutonium^{239}, uranium^{235}).

2. Radioactive substances distributed uniformly throughout the
body (carbon^{14}, sulfur^{35}, sodium^{24}, xenon^{127}, niobium^{95}).

3. Radioactive substances distributed in the internal organs but
having a favorite localization (iodine^{131} in the thyroid gland, lan-
thanum^{140} and cerium^{141} in the liver, ruthenium^{103} and ruthenium^{106} in
the kidneys, and cesium^{137} in the muscles). Kholin's classification
does not characterize the preferential distribution of all known iso-
topes in the body with sufficient completeness.

This problem requires further study.

More detailed data on the distribution of radioactive elements in
various organs are given in Table 6.

These figures have been made more precise as a result of later
experimental work.

The quantity of a radioactive substance which accumulates in a
given organ does not of itself determine the pathological changes in
that organ. For example, strontium concentrates in the bones, but in-
jures both the bones and the central nervous system. An accumulation
of radioactive substances in the spleen and lymph nodes causes changes
in the entire hematogenic system. In addition to its general influence,

TABLE 6

Preferential Accumulation of Radioactive Elements Administered Parenterally (According to Gamil'ton [Hamilton]

A Элемент	B Период полураспада	C % накопления	D Депонирующий орган
E Стронций-89	53 дня T	65	кости W
Стронций-90	20 лет U	65	кости
F Барий-140	12,8 дня	65	кости
G Цезий-137	33 года U	45	мышцы X
H Иттрий-91	57 дней	65	кости
I Лантан-140	40 часов V	65	печень Y
J Церий-141	28 дней T	55	печень
Церий-144	275 дней	25	кости
K Празеодим-143	13,8 дня	30	печень
		40	кости
L Прометий-61	3,7 года	50	печень
		30	кости
M Цирконий-95	65 дней	45	кости
N Рутений-103	42 дня	3,5	почки
Рутений-106	1 год U	3,5	почки
O Теллур-127	90 дней	15	кровь Z
Теллур-129	32 дня	6	почки AA
P Торий-234	24,5 дня	50	кости
Q Протактиний-231	$3 \cdot 10^4$ лет	40	кости
R Нептуний-239	22 дня	60	кости
S Плутоний-239	$2,2 \cdot 10^4$ лет	65	кости

A) Element; B) half-life; C) % of accumulation; D) organ where deposited; E) strontium; F) barium; G) cesium; H) yttrium; I) lanthanum; J) cerium; K) praseodymium; L) promethium; M) zirconium; N) ruthenium; O) tellurium; P) thorium; Q) protactinium; R) neptunium; S) plutonium; T) days; U) years; V) hours; W) bone; X) muscle; Y) liver; Z) blood; AA) kidneys.

a selective accumulation of radioactive substances in the bones retards their growth and reduces their regenerative capacity, causing painful osteites, "radiation" necroses, "spontaneous" fractures, and osteogenic sarcomas (I.M. Verkhovskaya, P.N. Kiselev, N.N. Petrov, B.N. Tarusov, et al.).

Excretion of Radioactive Substances from the Body

When a radioactive substance is administered orally up to 90% of it is excreted by the gastrointestinal tract. The heavy metals are almost completely excreted with the feces. A hundred times more lanthanum and cerium are excreted with the feces than with the urine; six

times as much cesium is excreted with the urine as with the feces. The rate at which radioactive substances are excreted from the organism depends on their chemical properties and the places at which they accumulate; highly soluble substances are rapidly excreted. These include sodium, cesium, and iodine, while polonium and praseodymium are excreted slowly and radium, uranium, barium, and strontium, i.e., the substances which accumulate in the bones, extremely slowly.

Radioactive substances with high atomic weights are the most difficult to excrete from the body. They unite with protein molecules to form conglomerates which cannot pass through the kidneys. These substances are excreted with the bile, in the form of colloidal solutions. There are indications that the toxicity of radioactive substances increases in the colloidal state. Those substances which form soluble salts and accumulate in the soft tissues are most easily excreted in the urine. Substances which are deposited in the bones are excreted extremely slowly. Gases are excreted most rapidly. Gaseous radioactive substances are excreted through the lungs, with the exhaled air, within 2-5 hours. Despite this, the respiratory passages retain their residual radioactivity for a considerable time (this radioactivity being due to solid residues). In nursing mothers a portion of the radioactive substances is excreted by the mammary glands, with the milk. As we noted above, the rate at which radioactive substances are excreted is related to their chemical and physical properties. The term effective half-life refers to the time required for the body to eliminate half of the radioactive substances which it has received.

The radioactivity of incorporated radioactive substances is directly reduced by two processes:

a) as a result of biological excretion;

b) as a result of the physical processes of radioactive decay.

TABLE 7

A Название изотопа	B Период полураспада (дни)	C Период полувыведения эффективный (дни)	D Примечание
E Натрий-24	0,62	0,60	Q Продукты наведенной радиации
F Калий-42	0,52	0,51	R то же
G Марганец-56	0,108	0,104	•
H Кобальт-60	1900	8,4	
I Стронций-89 . J	53	52	S осколки урана
Стронций-90 + иттрий-90	9100	2700	•
J Иттрий-91 L .	57	51	•
K Цирконий-95 + ниобий-95	65	48	•
M Ниобий-95	35	21	•
N Рутений-106	365	19	•
Иод-131 . P	8	7,5	•
O Церий-144 + празеодим-144	275	180	•

A) Isotope; B) half-life (days); C) effective half-life (days); D) notes; E) sodium; F) potassium; G) manganese; H) cobalt; I) strontium; J) yttrium; K) zirconium; L) niobium; M) ruthenium; N) iodine; O) cerium; P) praseodymium; Q) induced-radiation products; R) the same; S) uranium fragments.

The effective life of radioactive substances thus depends on their half-life and effective half-life.

Table 7 gives data on the effective half-lives of certain of the more dangerous isotopes, these being the products of atomic explosion and induced radiation.

All other conditions being identical, the longer the effective half-life the more intense will be the action of the incorporated radioactive isotope.

Chapter 3

ACUTE RADIATION SICKNESS

Action of Ionizing Radiations on the Living Organism

The biological action of ionizing radiations depends on the type
of radiation, the irradiation dose and time, and the condition and in-
dividual characteristics of the organism.

Different types of ionizing radiation have different biological
effects on the living organism. Hard x-rays, γ-rays, and neutrons have
a high penetrating power and cause radiation sickness on external ir-
radiation. Fast neutrons are more active biologically than x-rays.
Penetrating into tissue with high energy, they enter the nuclei of
phosphorus, sodium, sulfur, nitrogen, and other atoms included in the
makeup of the body and convert them to unstable radioactive atoms.
This gives rise to so-called "induced" radioactivity, which causes the
self-irradiation of the body to increase sharply.

Having only a slight ability to penetrate tissue, α- and β-par-
ticles acting from without primarily injure the dermal tegmina. Alpha-
and beta-active substances ionize the surrounding tissues when they
enter the body. The changes which they cause are described in a special
section. The character of the biological reaction depends not only on
the type of radiation, but also on many other factors. Thus, for exam-
ple, the higher and more complex the organization of the biological
entity irradiated, the greater its radiosensitivity. Mammals are con-
sequently more sensitive to penetrating radiation than the lower ver-
tebrates or cold-blooded animals.

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Not all organs of the living organism have the same sensitivity to penetrating radiation. The hematogenic organs and gonads, especially the tissue of the testes and ovaries, are most sensitive. The sterilizing and genetic action of ionizing radiation affects them the earliest. The most resistant organs and tissues are muscle, cartilaginous, and bony tissue. Only large doses of ionizing radiation are sufficient to injure them. It was shown above that the character of the biological reaction depends on: a) the reactivity of the organism; b) the localization and size of the irradiated surface; c) the intensity of irradiation; d) the irradiation dose.

The same irradiation dose may cause injuries of varying extent, depending on the reactivity and resistivity of the organism, factors associated with the resistance of the nervous system, immunobiological activity, the condition of the cardiovascular system, etc.

Among the factors which weaken the organism are hunger, fatigue, sleeplessness, and various injuries and diseases. Protein starvation, in which the nutrition of vitally important organs — the brain and heart — is disrupted, is especially detrimental. It greatly increases the sensitivity of animals to radiation and reduces their survival time after irradiation. Infants and the aged are most sensitive to ionizing radiation. The severity of injury depends to a considerable extent on the localization of the irradiated portion of the body. Irradiation of the abdominal organs is most dangerous. It yields the same effect as whole-body irradiation, i.e., causes radiation sickness. Irradiation of the extremities has the least effect with respect to the development of radiation sickness. The severity of a radiation injury also depends on the size of the irradiated area. Thus, for example, when the human body is subjected to whole-body β-irradiation in a dose of 400 r severe radiation sickness develops, while irradiation of

of a 20 x 20 cm area of the body in the same dose does not lead to ra-
diation sickness, being accompanied only by a brief reaction.

Acute radiation sickness develops on a single massive exposure to
ionizing radiation or on repeated irradiation in sufficiently high
doses. Prolonged irradiation of the organism in very small doses still
exceeding the maximum permissible levels can lead to the development
of chronic radiation sickness after many months or years. One of the
most important factors determining the severity of the biological re-
action is the irradiation dose. No visible symptoms of illness whatso-
ever develop on whole-body irradiation of man in a dose of 50 r. The
slight changes which occur in the blood in this case are rapidly re-
stituted without therapeutic measures and this dose is consequently
taken as the maximum permissible dose under particular conditions.

TABLE 8

Probable Results of Massive Whole-Body
Irradiation of Man

A Доза в рентгенах	B Следствие облучения	C % смертности людей
D от 0 E до 100	G Симптомов заболевания нет	0
от 100 до 200	Легкая степень лучевой болезни H	до 2
от 200 до 300	Средняя степень лучевой болезни I	от 5 до 15
от 300 до 500	Тяжелая степень лучевой болезни J	от 15 до 80
F свыше 500	Крайне тяжелая степень лучевой болезни K	от 80 до 100

A) Dose in roentgens; B) irradiation
sequelae; C) % mortality; D) from; E) to;
F) more than; G) no symptoms of illness;
H) mild radiation sickness; I) radiation
sickness of moderate severity; J) severe
radiation sickness; K) extremely severe
radiation sickness.

Table 8 gives rough data on mortality and the development of
acute radiation sickness as a function of absorbed dose on massive
whole-body irradiation.

The basic effect of ionizing radiations is the formation of ions.

Ionizing radiation primarily alters the body fluids, by ionizing water. The formation of the free radicals H, OH, HO_2, and H_2O_2 depresses the activity of enzyme systems, disrupts histogenesis, causes degenerative changes in the cells, and leads to a depression of tissue growth and regeneration.

As a result of ionization the complex molecules of proteins, fats, carbohydrates, salts, and other substances are converted to simpler toxic substances foreign to the organism which cause toxicosis. The nervous system plays the most important role in the further course of acute radiation sickness.

Irritation of the tissue receptors resulting in disturbance of their structure occurs at the instant when a radiative agent comes into contact with living tissue. The damaged receptors send an excess of stimuli into the central nervous system, throwing it into a state of extreme excitation (N.A. Kurshakov). Electroencephalographic investigation of patients at the beginning of radiation sickness indicates that the bioelectric activity and excitability of the cortex increase at this time.

The changes which develop in the various branches of the central nervous system cause a disturbance of nervous regulation, this being the basic factor in the development of further pathological processes, i.e., metabolic disturbances and distortions of organ structure and function. The phenomena involving the gastrointestinal tract which are characteristic of acute radiation sickness may serve as examples of such pathological processes; they include nausea, diarrhea, and vomiting, these being caused both by intoxication and by overexcitation of the neural apparatus. The depression of gastric secretion accompanied by achylia which is characteristic of the subsequent course of radiation sickness must also be associated with the state of the nervous

system, the neural apparatus which was overexcited during the initial period now being depressed.

While emphasizing the decisive role of the nervous system, Soviet authors by no means deny the significance of other important factors such as humoral influences. As is well known, during acute radiation sickness the blood is rich in toxic products, which enter it from the injured tissues.

The pathological processes may also cause humoral shifts to occur in the organism.

The current Soviet and foreign literature expresses the opinion that the hypophyseal-adrenocortical system plays a decisive role in the pathogenesis of acute radiation sickness (P.D. Gorizontov, V.B. Rozen, V. Lorents).

The activity of the hypophysis, which is a gland with a complex diverse function, is associated especially closely with the nervous system. At the beginning of the detrimental action of ionizing radiation the protective resources of the organism are mobilized by excitation of the sympathetic nervous system and secretion of adrenaline, which has a direct stimulatory action on the cells of the anterior lobe of the hypophysis (P.D. Gorizontov).

There is actually a marked increase in the functioning of the hypophysis at the beginning of radiation sickness. The hypophyseal hormones secreted into the blood stimulate the activity of other glands, primarily the adrenal cortex (Uayt, Patt). This phenomenon must be interpreted as a manifestation of the protective reaction of the organism to irradiation.

The role of the adrenal glands in the course of acute radiation sickness has long been known. Removal of these glands sharply increases the sensitivity of animals to the action of ionizing radiation, while

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the depression of their functioning observed at the height of acute radiation sickness has a negative influence on the course of the illness, causing a disturbance of hemodynamics and suppression of immunobiological reactions.

"In certain cases," says N.A. Krayevskiy, "we must take into account the role of changes in the adrenal glands as a direct cause of death."

All that has been said above confirms that endocrine changes have an undoubted influence on the character and course of acute radiation sickness.

The views of Soviet scientists on the mechanism underlying the biological action of ionizing radiations differ radically from those held by a number of foreign authors. Japanese investigators suggest that radiation has a direct action on the most radiosensitive tissues and organs. As A.V. Kozlova has noted, they do not consider the role of the nervous system. All of the numerous symptoms of radiation sickness are treated as secondary, developing as a result of direct injury to the hematogenic organs. In the opinion of certain authors, the nervous system is extremely resistant to penetrating radiation. The situation has been shown to be entirely different by numerous works by Soviet authors (I.R. Tarkhanov, M.N. Zhukovskiy, et al.), which hold that the nervous system is very sensitive to ionizing radiations. When an animal organism is exposed to ionizing radiation serious functional disturbances are first detected in the central nervous system.

While not denying the direct action of ionizing radiations on cells and the tissue destruction which they cause, Soviet scientists consider the neurotrophic disturbances which develop in the body as a result of changes in the functioning of the central nervous system to be of the greatest importance. Our scientists thus assign the decisive

role to the entire reaction of the organism as a whole, the nervous system playing the leading part.

<u>Symptomatology of Acute Radiation Sickness</u>

Various injuries and functional disturbances, the aggregate of which is called "acute radiation sickness," occur in persons subjected to irradiation in large doses.

This illness is characterized by a complex set of clinical symptoms which reflect the pathological processes occurring in all organ and tissue systems.

Acute radiation sickness is characterized by a phase-like course, it being possible to differentiate four periods:

1 — the period of initial reactions;

2 — the latent period (a period of seeming health);

3 — the period of marked clinical symptoms (the height of the illness);

4 — the recovery period.

The most marked periods of illness occur in 2nd- and 3rd-degree radiation sickness.

In addition to its theoretical interest, establishment of the phase-like character of the clinical course of radiation sickness is of great practical importance. Thus, transportation of casualties and requisite surgical intervention are more effective when carried out during the latent or, possibly, the first period than during the third period. Knowing the stages and sequence of the course of the illness makes it possible both to prescribe treatment at an opportune time and to take prophylactic measures. Thus, for example, administration of antibiotics is more effective during the first and second periods, before symptoms of bacteriemia appear, than during the height of the illness. Four degrees of severity may be distinguished for acute radia-

tion-sickness, in accordance with the markedness of the clinical symptoms and the severity of the course of the illness:

    I — mild;
    II — moderately severe;
    III — severe;
    IV — extremely severe.

The severity of radiation sickness depends not only on the dose of penetrating radiation received and the localization of the irradiation, but also on the reactivity or sensitivity of the organism in question.

The same irradiation dose may cause functional disturbances of varying extent in internal organs, this producing different radiation-sickness pictures. In evaluating the degree of radiation sickness, it is more correct to proceed from the biological effect of the irradiation, i.e., the clinical severity of the illness, than from the absorbed irradiation dose.

Periods in the clinical course of radiation sickness

The first period, that of the initial reactions, begins immediately after irradiation and lasts for from several hours to three days, depending on the extent of the injury; the victim develops a headache, dizziness, weakness, dryness of the mouth, and nausea and vomiting which are not associated with eating and do not alleviate his condition. The patient is excited, becomes insomniac, and has nightmares or delusions.

Loss of consciousness, meningeal phenomena, cardiac arrhythmia, and diarrhea are observed on irradiation in large doses. Dermal hyperemia and an increase in body temperature resulting from intensified heat production in protein decomposition occasionally occur. Certain changes in the blood (lymphopenia against a background of neutrophilic

leucocytosis and a slight erythrocytosis accompanied by a decrease in erythrocyte stability) appear during this period.

On the basis of clinical and experimental data, I.N. Ivanov concludes that the character of the initial reaction may indicate the severity of the injury. According to the author's data, radiation sickness proceeds more severely as the initial reaction develops earlier and is more acute. According to the data of A.V. Kozlova, A.N. Kurshakov, I.S. Glazunov, and I.K. Guskov, there is a complete correspondence between the severity of acute radiation sickness and the character of the initial reaction.

In the extremely severe form of this illness the initial reaction takes the form of a brief excitation followed by loss of consciousness, a shock-like state, prostration, delirium, and unrestrainable vomiting. These symptoms appear immediately after irradiation and pass directly into the severe form of the illness with no latent period.

In the severe form of radiation sickness the initial reaction develops 1-2 hours after irradiation and continues for 1-5 days, being marked by excitation, insomnia, intense headaches, nausea, and vomiting.

In addition, tachycardia, extrasystole, diarrhea, and thirst may appear.

In the moderately severe form of radiation sickness the initial reaction develops 3-5 hours after exposure to ionizing radiation. The same symptoms are observed as in the severe form, but they are less marked. All of the symptoms usually last 1-2 days.

In the mild form of radiation sickness the initial reaction is not very marked. It appears several hours after exposure to ionizing radiation and fades away during the first few days. It may be entirely absent.

The second (latent) period is the period of apparent health. Its
duration depends on the severity of the illness. In serious cases the
latent period is either entirely lacking or lasts only several hours.
In the mild and moderately severe forms of the illness it lasts up to
3-4 weeks. The shorter the latent period of the illness, the more seri-
ous is the prognosis. The period of initial reactions gradually fades
away and the patient feels himself to be considerably better, his diz-
ziness and headache having disappeared, his sleep and appetite having
improved, and the dyspeptic phenomena either having decreased or dis-
appeared; the only remaining symptoms are weakness and loss of appe-
tite. This period is called the period of seeming health, since dis-
turbances continue to develop in many of the organs and systems of the
victim's body despite his lack of complaints and his relatively good
opinion of his own condition. The previously intensified secretion of
gastric juice now becomes depressed and leucopenia appears to replace
the leucocytosis. The lymphopenia, leucopenia, and thrombopenia gradu-
ally increase. These hematological phenomena are so constant that they
are used for diagnosing the illness during its latent period.

In the severe form of the illness the pulse accelerates and the
arterial pressure decreases during this period; any slight physical
stress intensifies the tachycardia and causes dyspnea. Body temperature
may be either elevated or normal.

The third period, that of marked clinical symptoms, lasts from
the 7th-10th to 20th-25th days, depending on the severity of the ill-
ness. The vomiting, diarrhea (frequently with an admixture of blood),
headache, and dizziness resume and ulcerations appear in the mucosa,
being especially numerous throughout the gastrointestinal tract.

Bacteriemia develops easily in the presence of the widespread ul-
cerative processes in the gastrointestinal tract. The resistivity of

the organism being sharply reduced, the sapro-
phytes and numerous microorganisms become patho-
genic and a clinical picture of general sepsis
appears.

One of the early symptoms of sepsis and a
concomitant of the intercurrent infections is a
rise in body temperature from subfever levels
to 39-40°, depending on the severity of the in-
jury. An acute radiation affection may have a
lethal outcome as a result of either infectious
complications or severe hemorrhaging.

Bleeding from the capillaries and vessels

Fig. 6. Hemor-
rhages in the mu-
cosa of the small
intestine.

of the dermal tegmina and the mucous membranes

takes the form of ecchymoses, petechiae, vomit-
ing of blood, nosebleeds, menorrhagia, spitting blood, and hematuria
(Fig. 6). The localization of the hemorrhages determines the clinical
picture of the illness. Hemorrhages in the internal organs, especially
the respiratory and digestive apparatus, may cause subsequent complica-
tions. Pulmonary hemorrhages give rise to focal pneumonia. Hemorrhag-
ing in the digestive tract produces inflammatory and ulcerative proc-
esses and their accompanying symptoms. Hemorrhages in the vitally im-
portant organs (heart, brain, and spinal cord) are especially danger-
ous (Figs. 7-10).

The hemorrhagic phenomena do not always develop simultaneously
with the drop in leucocyte count and the increase in blood clotting
time, also being due to the fragility of the vessels and the increased
permeability of the vascular walls which results from disturbance of
their trophics.

The trophic changes also take the form of brittleness of the

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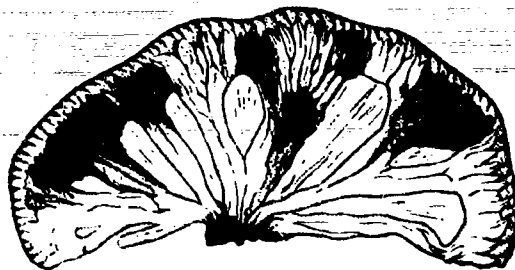
Fig. 7. Hemorrhages in the serous
membrane of the small intestine and
the mesenterium tenue.

nails and loss of hair from the head and other hairy portions of the
body.

The decrease in leucocyte count which began during the latent
period becomes very marked. A leucopenia of 2000 cells/mm^3 is the fore-
runner of an extremely serious prognosis, a drop to 500 leucocytes per
mm^3 frequently indicating irreversibility of the phenomena occurring.
The granulocyte count reaches zero in severe cases. There is a gradual
increase in the lymphopenia and thrombopenia. In addition to a decrease
in the number of erythrocytes in the peripheral blood and a sharp drop
in their osmotic resistance, reticulocytes may appear when the illness
takes a favorable course, this indicating the beginning of a restora-
tion of hematogenesis. Extremely marked functional disturbances occur
in all organs and systems during the height of radiation sickness, as
does a change in metabolic processes; the latter is described in the
following section. This period passes into the recovery phase when the
illness takes a favorable course.

The fourth period, or the recovery period, sets in extremely
slowly. The patient's condition improves, the painful symptoms becom-
ing less marked and gradually disappearing. The appearance of reticulo-
cytes indicates a favorable outcome. The blood is usually not com-
pletely normalized. Patients who have recovered from radiation sick-
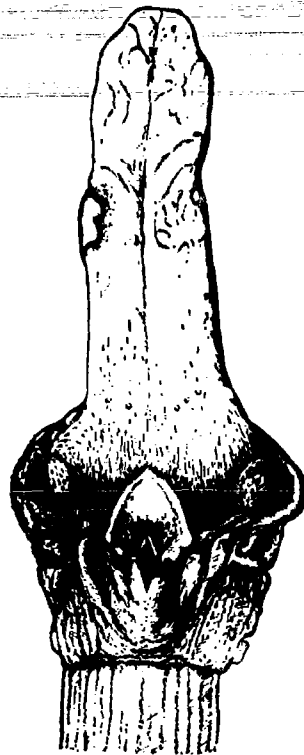
Fig. 8. Necrosis of a tonsil.
Widespread hemorrhaging in the
mucosa of the pharynx. Ulcers
in the mucosa of the tongue.

ness continue to exhibit leucopenia and anemia for many months. The
signs of bleeding gradually disappear. The dermal tegmina remains some-
what pigmented, but the hair grows out. Body temperature is normalized,
this usually being associated with suppression of the infectious proc-
esses, occurrence of epithelization, and a decrease in the inflamma-
tory processes in the necrotic and ulcerated areas. The functioning of
various organs and systems is gradually restored and the patient re-
gains his appetite when the dyspeptic phenomena and diarrhea cease.
The headaches and insomnia disappear, although a susceptibility to
rapid fatigue, weakening of the memory, and increased irritability
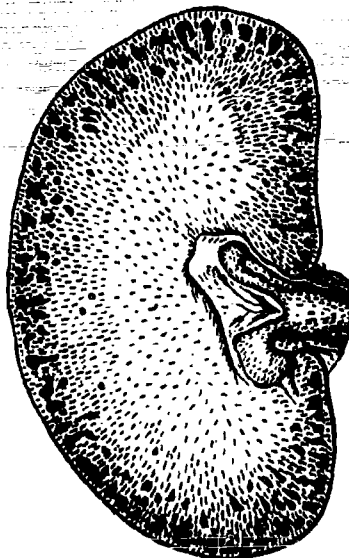
Fig. 9. Multiple pete-
chial hemorrhages in the
cortical layer of the
kidney.
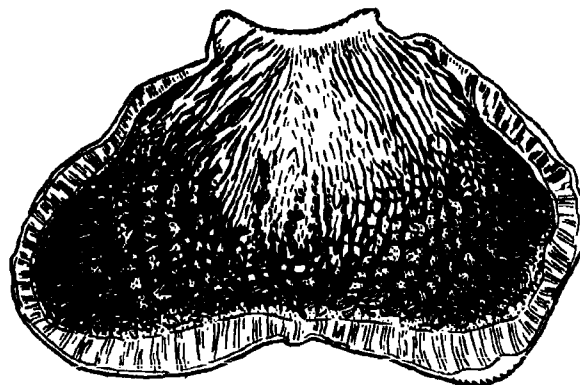
Fig. 10. Hemorrhages in the wall of the
urinary bladder.

persist for a long time. Complete recovery and disappearance of all
pathological symptoms usually occurs in the mild (and occasionally the
moderately severe) form of the illness. The symptomatology of radia-
tion sickness includes a periodic deterioration of the patient's con-
dition, this regularly being succeeded by an improvement. This wave-
like course is also observed in those cases where the acute stage of
the illness becomes chronic.

Degrees of severity of acute radiation sickness

Depending on the severity of its clinical course, four forms of
acute radiation sickness may be distinguished: extremely severe, se-
vere, moderately severe, and mild.

The fourth degree, extremely severe, was observed in persons ir-
radiated in extremely large doses in the cities of Hiroshima and Naga-
saki. The clinical picture of this form is the least well studied,
since the patients died very rapidly. The illness set in immediately

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after irradiation and continued for from several hours to two weeks, most frequently terminating in death during the first two days. Adynamia and prostration set in after a period of severe excitation. The most seriously injured exhibited convulsions and uncontrollable vomiting, were delirious, and occasionally displayed meningeal phenomena and loss of consciousness. Body temperature gradually increased, reaching 39-40° for several days, and did not decrease until death. The victims died exhibiting symptoms of disturbances of the respiratory and cardiovascular systems.

The third, or severe, degree develops immediately after irradiation or an hour or two later. The first period of the illness lasts for from one to five days, being characterized by severe excitation, headaches, dizziness, insomnia, and occasional delirium and meningeal phenomena. A liquid stool is passed up to 10-20 times a day and there is abdominal pain and hiccuping. The gastric hypersecretion which occurred during the phase of increased excitability is soon replaced by a depression of secretion which occasionally extends as far as achylia. The opposite of the phase of increased excitation sets in, i.e., protective inhibition of the nervous system. The symptomatology of this phase includes adynamia, prostration, a decrease in muscle tonus, and a drop in blood pressure. Dyspnea, tachycardia, and arrhythmia appear and hematuria, nosebleeds, and bleeding from other organs are occasionally observed during the initial period.

The patient's condition improves and the latent period of the illness sets in on the 2nd-5th day after irradiation; this period lasts from two to five days. All of the symptoms of the illness with the exception of severe weakness disappear during this period and the patient occasionally regains his appetite. The elevated temperature, tachycardia, and hypotonia are still noted.

The third period of the illness begins on the 10th-12th day and lasts for up to two months. The severe headaches, dizziness, nausea, and vomiting reappear. The dyspnea, tachycardia, and arrhythmia are again intensified and the arterial pressure drops still lower. The tongue and oral mucosa become dry and hemorrhages, cracks, and ulcerations appear in them. The diarrhea acquires a hemorrhagic character as a result of ulcerations along the intestine. Changes in the motor and secretory functions of the gastrointestinal tract seriously disrupt absorption and this further promotes emaciation of the patient.

One of the threatening symptoms of this form of the illness is bleeding. Hemorrhages develop not only in the skin and mucosa, but also in the internal organs, this being the determining factor in the further clinical picture of the illness. Thus, for example, hemorrhaging in the myocardium is accompanied by a clinical picture of myocardial infarct. Hemorrhages in the pleural cavities and lungs cause a clinical picture of hemorrhagic pleuritis and pneumonia. The localization of hemorrhages in the brain determines the complex neurological symptomatology. When the resistance of the organism is reduced hemorrhages are a predisposing factor for secondary infection and for a septic condition when the latter generalizes. Body temperature remains at high levels during all periods of the illness. The symptoms of general intoxication become more intense and the blood exhibits lymphopenia, leucopenia accompanied by a sharp formula shift to the left, and degenerative changes in the leucocytes; the anemia becomes more intense. Death may result from hemorrhages in the vitally important organs, paralysis of the respiratory and vasomotor centers, or a concomitant secondary infection, most frequently pneumonia.

The recovery period extends over a very long time. Improvement alternates with relapses and complications. Complete recovery does not

occur.

The asthenia of the central nervous system persists for an especially long time; patients are apathetic and inactive and their memories are disorganized for a prolonged period.

The second degree, radiation sickness of moderate severity. The initial reaction develops during the first few days, frequently within 3-5 hours after exposure to ionizing radiation. The symptoms observed are the same as those of the severe form of the illness, but are less marked. The period of excitation is soon succeeded by apathy and adynamia, stubborn headaches developing. Weakness, nausea, repeated vomiting, loss of appetite, and a liquid stool passed up to 5 times are noted during the first day of illness. Body temperature rises to 37-37.5° and tachycardia and hypotonia appear.

All of these phenomena gradually abate on the 2nd-3rd day and the illness passes into the latent period, which lasts for from two to three weeks. The blood exhibits leucopenia (1000-3000 cells/mm^3) accompanied by a shift to the left, toxic granularity in the neutrophils, and a moderate anemia. Partial epilation of the hairy portion of the head is observed at the end of the latent period. The hair thins out considerably or drops out in bunches. Complete baldness occurs only now and again.

The third period begins with an increase in temperature to 38-38.5° and a deterioration of the patient's general condition. The headaches, nausea, and vomiting reappear and a liquid stool is passed frequently. Blood can be detected only microscopically in the feces and urine. The nervous system exhibits unstable pathological reflexes (Gordon's, Babinskiy's, and Rossolimo's) and nystagmoid movements of the eyes.

The pulse rate accelerates and becomes labile and blood pressure drops.

As A.V. Kozlova has shown, petechiae are observed in the skin of 10-15% of patients, most frequently appearing during the 5th-6th week of illness and having a miliary character.

Ulcerations rarely develop in the oral cavity and along the gastrointestinal tract, the changes in the oral mucosa generally being limited to swelling and erubescence. The hematological changes and other clinical symptoms are distinguished from those of the severe form only by their lesser intensity.

Jaundice is rarely observed. Despite a slight enlargement of the liver, this organ exhibits no substantial functional disturbances.

The functions of the liver are reestablished after 3-4 months in young persons and considerably later in the elderly. All of the symptoms of the illness last approximately two months. The recovery period begins with a drop in temperature, an improvement in the patient's opinion of his own condition, and cessation of the headaches. The inflammatory phenomena in the oral mucosa gradually abate and the stool becomes normal. However, a predisposition to disturbances of the gastrointestinal tract persists for a long time and the patient's resistance to infectious diseases is reduced. Relapses during this period occur somewhat less frequently than in the severe form, taking the form of a new increase in body temperature, a deterioration of the patient's general condition, and the passing of a liquid stool (A.V. Kozlova).

A patient who recovers from this illness still exhibits a susceptibility to rapid fatigue and a loss of memory for a considerable time.

The first, or mild, degree of radiation sickness. In this form of the illness the initial reaction develops several hours after irradiation and fades away within 1-3 days, it being possible for the malaise, headache, and weakness to be entirely absent. During the latent period,

which lasts for from 4 to 5 weeks, the illness is manifested only in a moderate lymphopenia and leucopenia. No clear dividing lines can be detected between the periods. The leucopenia generally does not drop below 2000-3000 leucocytes per mm^3 during the period of marked clinical symptoms. The anemia (which is frequently marked) and other changes in the blood are usually normalized within 2-3 weeks. Patients subjectively note periodic headaches, dizziness, weakness, and loss of appetite. There are isolated petechiae in the skin and mucosa. The functional changes in the patient's organs and systems are slight, the most obvious being a tendency to diarrhea. The capacity for work is completely restored in the mild form of radiation sickness.

Functional Changes in the Body under the Action of Ionizing Radiations

The mechanism by which radiation sickness develops is an extremely complex process. The reaction of the entire organism involves all organs and systems in the pathological process. The neurological symptomatology of radiation sickness is nonspecific and depends not only on changes in the nervous system itself, but also on intoxication, anemia, concomitant infections, and other factors.

The nervous system. A brief excitation of the central nervous system occurs at the beginning of the first period, this being succeeded by protective inhibition. Stimulation of the receptor apparatus causes hyperesthesia, hyperacusis, photophobia, and olfactory hallucinations. Investigation of cerebral biotics reveals an increased excitability and bioelectric activity. Nausea and vomiting develop when the vestibular apparatus is stimulated and nystagmus is observed. Muscle tonus increases at first, but this is succeeded by sluggishness, adynamia, and trembling of the outstretched hands. The dermal, tendon, and periosteal reflexes are strong and nonuniform in a number of cases, meningeal symptoms occasionally being observed; these latter include

slight Kernig's and Laseque's signs and rigidity of the occiput. The diffuse overexcitation of the central nervous system enables it to pass into a state of protective inhibition. N.A. Kurshakov notes that generalized massive stimulation of the receptor apparatus leads to extremely severe trauma to the central nervous system, a factor which may cause a shock-like state. All of the symptoms abate during the second period, but the adynamia, asthenia, apathy, and prostration persist. During the third period, that of marked symptoms, the headaches return. They are stubborn and severe in character, resembling the headaches which occur in tuberculous meningitis. Insomnia and nightmares occur. Symptoms of increased intracranial pressure appear, this explaining the dizziness, nausea, and uncontrollable vomiting which occurs during this period. The presence of increased intracranial pressure is also indicated by congestive phenomena and petechial hemorrhages in the ocular fundus. Frequent cerebral hemorrhages are noted during this period. The site of the hemorrhaging also determines the symptomatology.

Subarachnoid hemorrhages cause sudden losses of consciousness and intensify the meningeal symptoms. Just as when hemorrhages occur in the cerebral matter, the presence of subarachnoid hemorrhages gives rise to an unfavorable prognosis, since they are accompanied by disturbances of respiration and cardiac activity. Recovery depends to a considerable extent on the severity of the functional disturbances in the central nervous system. Complete recovery does not occur in the severe form of the illness. The increased irritability, trophic disturbances, and emaciation persist for a long time.

The skin and mucosa. During the initial period of the illness the dermal tegmina are either severely decolorized or hyperemic, hyperemia of the ocular conjunctiva being especially marked. Irradiation of the

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region of the salivary glands causes dryness of the mouth as a result of depression of the functioning of these glands. In the severe form of the illness the skin becomes dry and brittle as a result of atrophy of the fat and sweat glands. There is no sweat secretion, even when the temperature is increased considerably. During the third period of the extremely severe form of the illness petechiae and hemorrhages appear in the skin of the entire body. These occur in only 5-15% of cases of the moderately severe form of radiation sickness (A.V. Kozlova).

The mucosa of the oral cavity, gingiva, and pharynx become crubescent and swollen and their sensitivity to heat, cold, stimulants, and mechanical injury increases. In the very severe and severe forms of the illness ulcerations (which may reach the necrotic stage), paratonsillary abscesses, and necrotic anginas occur in the mucosa. Atrophic and subatrophic catarrhs accompanied by the formation of scabs and erosions develop in the mucous membranes of the upper respiratory passages.

While epilation of all hairy areas of the body is noted from the 10th-15th day onward in the severe form of the illness, in the moderately severe form baldness begins later, on the 15th-20th day and is limited to isolated portions of the hairy section of the head or thinning out of the hair. In these patients hair begins to grow back 4-5 weeks after it is lost. As a result of atrophy of the hair bulbs restoration is only partial in the severe form of the illness, occurring in the less affected regions.

The hairs which grow out after epilation are dry, thin, brittle, and gray in places. Healing of the ulcerations in the mucous membranes during the recovery period takes an extremely long time. Irradiated portions of the skin remain pigmented for a prolonged period.

The cardiovascular system. No specific changes develop in the cardiovascular system during acute radiation sickness. Tachycardia, occasionally accompanied by arrhythmia, is observed during the initial period. Blood pressure drops to a hypertonic level and is normalized only during the fourth period. There is an especially marked increase in the permeability of the vascular walls during the third period. When there is hemorrhaging in the myocardium the clinical picture resembles that of myocardial infarct. A labile rhythm and, occasionally, single extra systoles are detected during the initial period. The heart is usually somewhat enlarged in cross section. Its sounds are dull during the height of the clinical symptoms, a systolic murmur occasionally being heard at the apex. An electrocardiogram shows a decrease in voltage at all leads, leveling of peaks, and other changes characteristic of myocardial dystrophy. Seriously ill patients exhibit prolongation of the ST interval, compression and attenuation of the peaks, and disturbance of intraventricular conductivity (A.V. Kozlova).

The respiratory organs. Functional disturbances appear in the respiratory organs in all forms of radiation sickness. Victims exhibit dyspnea and a wracking dry cough during the period of initial reactions. Cheyne-Stokes' respiration appears in severe cases. Stabbing pains develop in the thoracic cavity as a result of reactive dry pleuritis, these becoming more intense during respiration and coughing. As G.A. Zadgenidze has noted, respiration becomes deeper and slows down, occasionally being arrhythmic, while pneumatization of pulmonary tissue is considerably reduced as a result of the increased filling of the vascular network. Pneumatization of pulmonary tissue is reduced or hypoventilation and atelectasis develop in various sections of the lungs. Dilation of the lumens of the large bronchi and constriction of those of the small bronchi (or vice versa) is observed during this

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period, an increase in bronchial tonus accompanied by development of emphysema setting in later, during the height of the radiation sickness.

Clinical examination of the patients reveals a reduced respiratory excursion of the lungs, the percussion note acquiring a bandbox shading. Diffuse dry rales are heard against a background of attenuated vesicular respiration. A large number of dry babbling rales appear during the height of the clinical symptoms, edema of the lungs setting in in severe cases. N.M. Amosov explains this phenomenon as being due to the fact that the developing acinous pneumonia takes the form of pulmonary edema as a result of the increase in vascular permeability. The pleura are often simultaneously affected, this explaining the pain in coughing and breathing.

Against a background of increased penetrability of the lung fields, x-rays of the thoracic cavity reveal an intensified pulmonary pattern with acinous shadow sections. The shadow areas usually correspond to regions of hemorrhaging and pneumonic foci.

The acute or chronic focal pneumonia which develops during the height of the third period complicates the clinical course of the illness.

The gastrointestinal tract. Loss of appetite, nausea, vomiting, dryness of the mouth, and thirst develop during the first period. The abdomen becomes painful. The acidity of the gastric contents increases briefly. The dyspeptic phenomena and abdominal pains become more intense during the third period. The tongue becomes dry and furred or glossy. Ulcerations develop in the oral cavity and along the entire course of the gastrointestinal tract, these frequently giving rise to secondary infection. In the serious form of the illness the ulcerations and necrotic areas may cause perforations and this produces a clinical

picture of acute abdomen. As a result of a decrease in tonus individual loops of the intestine are greatly extended, this frequently causing a clinical picture of paralytic obstruction. The initial brief increase in gastric secretion is followed by a prolonged depression, the total and free acidity of the gastric juice decreasing; this reduces its digestive capacity. At the same time, there is a considerable decrease in pepsin activity (A.M. Vorob'yev, E.B. Glikson, et al). In studying the influence of ionizing radiation on the function of the pancreas, R.F. Raukh was able to detect a disruption of the digestive capacity of the pancreatic juice and a decrease in trypsin activity. Absorption is severely disturbed as a result of the disruption of the secretory and motor functions of the intestine, this leading to emaciation of the patient. Diarrhea (frequently with an admixture of blood) develops. In addition to the changes in the gastrointestinal tract, there are functional disturbances in the liver and gall bladder. Experimental data (A.I. Merkulov) have shown that disturbances of the secretory, concentrational, and evacuatory functions occur in acute radiation sickness. The dyspeptic phenomena gradually disappear during the fourth period. The loss of appetite is the most persistent effect. The acidity of the gastric contents usually remains reduced.

The urogenital system. Even when the patient has not eaten, a transient polyurea develops during the first period, this being succeeded by passage of a reduced amount of urine. Passage of a reduced quantity of urine with a low specific weight is observed throughout the entire course of the extremely severe form of the illness. This urine contains protein and a large quantity of erythrocytes and leucocytes from the first day of illness. The chloride and residual-nitrogen content of the blood increases simultaneously. During urography, G.A. Zadgenidze noted a depression of the secretory function of the kidneys.

In this case serogozin secretion lasts for up to 300 minutes rather than the usual 40-80 minutes.

The disturbance of the sexual function depends on the extent of the radiation injury. In males the sexual urge is decreased and the number of spermatozoa and their mobility are reduced to the point of complete sterility. Various disturbances of the menstrual cycle appear in females, most frequently amenorrhea. In pregnant females irradiation can cause death of the fetus and abortion. Females who have recovered from radiation sickness are frequently sterile, but if they become pregnant the infants are frequently stillborn or underdeveloped.

The blood system. Stimulation of the hematogenic organs occurs during the initial period. As a result of the deposited blood and the excitation of the hematogenic organs the quantity of all formed elements except lymphocytes increases; the latter decrease sharply during the first few days. At the beginning of the illness there is a manifest neutrophilic leucocytosis which is of prognostic value; the more marked this leucocytosis, the more severe will be the course of the illness. Subsequently there is a marked shift to the left and toxic granularity and hypersegmented forms of neutrophils appear. The resistance of the erythrocytes decreases. A depression of hematogenesis sets in during the second period, reaching complete suppression in severe forms of the illness. The number of formed elements decreases as a result of hypoplasia and cell destruction. The quantity of cells with short lifetimes drops first. The life of a lymphocyte is approximately one day, but it becomes even shorter under the influence of irradiation; there is consequently a marked lymphopenia at the end of the first day, this progressing until the lymphocytes disappear. The lifetime of neutrophils is 5-6 days. On the 3rd-4th day the number of these elements decreases and a shift to the right occurs because of

after irradiation. This process has a distorted character at first, resulting in the appearance of young formed elements; regeneration of lymphoid tissue consequently proceeds so slowly that the number of lymphocytes in the peripheral blood remains at a reduced level for a prolonged period.

The leucopenia continues to increase during the third period. In the severe form of the illness it reaches 2000 cells/mm^3, a drop to 500 leucocytes per mm^3 being an extremely menacing sign. Quite marked destructive changes are observed in the leucocytes; these include vacuolization, toxic granularity, purplish-brown tinting, nuclear pyknosis, decolorization, nuclear distension, and enlargement (A.V. Kozlova). The thrombopenia is accompanied by a hemorrhagic syndrome. The erythrocyte count is the last to decrease (the lifetime of an erythrocyte reaching 120 days). Anemia begins to appear during the second to third week. However, as A.A. Bagdasarov has shown, intensive erythrocyte destruction occurs from the 2nd day after irradiation onward, this being confirmed by the increased daily bilirubin content. Because of the redistribution of blood the decrease in the erythrocyte content of the peripheral blood usually does not appear until considerably later. The more serious the form of the illness, the more severe and marked is the anemia which develops. In certain cases erythropoiesis is distorted and proceeds in an embryonic fashion, large hemoglobin-saturated erythrocytes of the megalocyte type being formed; in such cases hyperchromic anemia develops and the color index increases to a value greater than unity.

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Regenerative phenomena are observed during the fourth, or recovery period. The number of lymphocytes and neutrophils increases and young forms, myeloblasts, promyeloblasts, and myelocytes appear. A shift to the left again appears in the white-blood formula. The number of erythrocytes and thrombocytes gradually increases. Hemopoiesis gradually returns to normal in complete recovery.

Protein metabolism. A whole series of pathological processes (depression of gastric secretion, a decrease in the digestive capacity of the gastric juice, and ulceration in the mucosa) develop in the gastrointestinal tract soon after irradiation, disrupting normal protein absorption. The problem of the influence of ionizing radiation on the digestion, absorption, and assimilation of protein nutrients was studied by I.I. Ivanov and T.A. Fedorova. It is obvious from the data which they obtained that animals exhibit both incomplete digestion of proteins in the stomach and retarded assimilation of amino acids into the tissues during radiation sickness. Such a disruption of basic trophic processes causes animals to become emaciated and lose weight.

One of the most characteristic symptoms of acute radiation sickness is the development of a negative nitrogen balance. This is caused both by disturbance of trophic processes and intensified tissue decomposition. At the same time that the negative nitrogen balance develops the total nitrogen secreted in the urine increases, this also being characteristic of radiation sickness. The content of uric acid and creatine in the urine also increases. There are also observations which indicate that the residual nitrogen content of the blood of irradiated animals is increased, this applying particularly to creatine and urea.

The disruption of the normal composition of the plasma protein fractions becomes especially marked during the third period of the illness. There is a decrease in albumins and an increase in globulins,

this leading to a decrease in the albumin-globulin coefficient. This change in the plasma protein composition is partially due to the functional insufficiency of the liver, in which serum proteins are synthesized, and this phenomenon consequently has a certain prognostic importance. The considerable changes in nucleoprotein metabolism should also be mentioned. These compounds are subject to intensified decomposition during the third period of radiation sickness and this is followed by a sharp drop in the nucleic acid content of various tissues and organs. This phenomenon is quite detrimental to protein metabolism as a whole, since nucleic acids play an important role in protein-synthesis processes.

Almost all antibodies and enzymes are proteins and disruption of the synthesis of these compounds inhibits fermentative processes and reduces the general resistance of the organism. When the illness has a favorable course all of these phenomena are normalized during the fourth period.

Carbohydrate-phosphorus metabolism is disrupted several hours after the beginning of the illness; the blood sugar content decreases to 140-170 mg/M, this leading to glycosuria. The glycemic curve acquires a diabetic character. During the first period of the illness the glycogen content of both the blood and liver of experimental animals increases. Beginning with the second period of the illness, the quantity of glycogen in the liver decreases sharply. The basic cause of this depletion of hepatic glycogen is the state of starvation characteristic of radiation sickness which develops in the animals as a result of disturbance of the digestive functions of the gastrointestinal tract. In the severe form of radiation sickness the hepatic glycogen content decreases sharply during the third period, possibly dropping to zero, a phenomenon which may be associated with intoxication of the organism

by the products of tissue decomposition in addition to starvation.

During the fourth period of the illness both the hyperglycemia and the glycogen content of the blood are gradually normalized. The most characteristic feature of carbohydrate metabolism during acute radiation sickness is the extreme instability of the blood sugar level, this being caused by radiation damage to the nerve centers which regulate carbohydrate metabolism. The content of phosphorus compounds (adenosinetriphosphoric and adenosinediphosphoric acids and creatine phosphate) in the spleen and small intestine decrease by a factor of 2-3 during the initial and latent periods of acute radiation sickness and remain at that level until the recovery period.

The biosynthesis of energy-rich phosphorus compounds in the skeletal muscles, liver, and brain is not disrupted.

Fat metabolism. Numerous investigations by Soviet authors (S. Nikitin, N. Buzin, L. Larionov, et al.) have shown that fatty infiltrations develop in the liver, kidneys, and other tissues of animals as a result of acute radiation injuries. Lipemia regularly occurs during the later stage of radiation sickness.

When the hepatic glycogen supply is exhausted compensatory mobilization of fats from the fat depots occurs under the influence of neurohumoral mechanisms, taking the form of shifting of considerable quantities of neutral fat from the fat depots to the liver. Thus, both lipemia and fatty infiltration of the liver are biologically useful reactions, augmenting the reduced energy resources of the body. According to observations made by certain authors, disruptions of fat metabolism usually increase in severity as depletion of the hepatic glycogen supply becomes more complete. As a result of the substantial depression of oxidative processes fats are oxidized only to ketones, the quantity of these compounds in the blood increasing sharply; this may

cause the onset of acetonuria. The latter is frequently observed in severe forms of radiation sickness or during the terminal stages of the illness.

Mineral metabolism. Acute radiation sickness is accompanied by a considerable disturbance of water-salt metabolism. The most important deviation from normal is a negative sodium, potassium, and chlorine balance. The majority of authors (F. Redlikh, P. Neyda, et al.) observed a marked decrease in the serum chloride and sodium contents of the blood of irradiated animals. Excretion of sodium chloride occasionally increased immediately after irradiation, indicating that this change has a neural-reflex character. In addition to this basic cause, the mineral-salt balance may deviate from normal as a result of the disturbance of salt absorption from the intestine which is observed during radiation sickness, as well as because of diarrhea, which causes a loss of sodium chloride and a dangerous dehydration of the body. The functional insufficiency of the adrenal cortex which occurs during radiation sickness also warrants mention. This takes the form of a loss of hormonal substances, including the hormones which regulate the potassium and sodium content of the blood.

Thus, a number of conditions which affect mineral metabolism are created during radiation sickness.

I.I. Ivanov points out that the disturbance of water-salt metabolism which occurs in the presence of radiation injuries has long been known to roentgenologists and radiologists. In order to prevent these phenomena, and particularly to eliminate nausea and headaches, the latter have successfully prescribed alkaline mineral waters and solutions of table salt for irradiated persons. In a purely practical manner, proceeding from actual observations, radiologists thus concluded that it was necessary to correct the deficiencies in the salt balance during

radiation sickness. This problem warrants especially serious attention and further study. In addition to deficiencies of sodium, chlorine, and potassium, acute radiation sickness is also characterized by changes in acid-alkali equilibrium, the alkali reserves of the blood decreasing.

Certain authors explain the initial acidosis as being due to the formation of a large number of acid valences in irradiated organisms as a result of tissue decomposition.

Pathologoanatomical Changes in Acute Radiation Sickness

In addition to functional disturbances, numerous organic changes occur in the animal organism during acute radiation sickness induced by external irradiation; the character of these changes is determined both by the irradiation dose and by the reactivity of the irradiated organism.

The earliest and most substantial changes occur in the hematogenic organs (bone marrow, lymph nodes, and spleen).

N.A. Krayevskiy notes certain regularities in the processes which occur in the bone marrow as a result of exposure to ionizing radiation. Thus, at the beginning of the illness the production of blood cells in the bone marrow is markedly accelerated and they are ejected in large quantities into the blood stream. Mobilization of the protective mechanisms of the organism and an intensification of metabolic processes also occur.

The intensified hematogenesis in the bone marrow drops somewhat during the latent period and exhibits signs of a slight normalization. During the period of marked symptoms dystrophic changes come to predominate over inflammatory changes, this indicating a depression of physiological protective mechanisms.

Turning to a description of the lymph nodes, it must be noted that

the lymphocytes and the entire lymphopoietic system are especially sensitive to the action of ionizing radiations.

Decomposition of lymphatic elements is observed very early in the lymph nodes. This period of destructive changes is soon succeeded by an atrophic process. In examining the spleen and lymph nodes it may be ascertained that the lymph follicles atrophy markedly during the initial period.

The changes in the spleen merit attention because hemopoiesis occurs in this organ. After a slight intensification of hematogenesis, a severe depression of lymphopoiesis sets in and the lymphocytes disappear. Substantial morphological changes are noted in the nervous system as well as in the hematogenic organs. The investigations of V.V. Portugalov show that structural damage is present in various branches of the nervous system at the height of radiation sickness. The degenerative changes which occur in the nerve cells take the form of demyelinization of nerve fibers and vacuolization of their membranes. It is possible for irreversible necrobiotic processes to develop later. Histological examinations shows that not all of the sections of the brain and spinal cord are altered identically. Destructive changes are observed in certain of them, while others exhibit reactive changes, which are reversible (N.A. Kravkov, V.V. Portugalov).

In L.A. Orbeli's opinion, the most marked changes occur in those structures which are in an active state at the instant of irradiation.

The sensitivity of nerve tissue to ionizing radiation also depends on the subject's age. Thus, the brains of young animals and of the fetus particularly have a high radiosensitivity. As the animals grow their nerve tissue becomes more resistant to the injurious action of ionizing radiation.

In studying the morphological changes which occur in the brain in

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the presence of radiation injuries, the Japanese scientist Shiraki was able to detect ischemic phenomena, petechial hemorrhages, vacuolization of the ganglion cells of the motor centers of the brain stem, and sclerosis of the ganglion cells of the entire brain.

The most characteristic and indicative symptom of radiation sickness is bleeding. This includes dermal ecchymoses and hemorrhages in the mucous membranes of the brain and gastrointestinal tract, the epicardium, and the pulmonary parenchyma. This hemorrhagic syndrome is most severe during the first half of the second period of radiation sickness. The bleeding is frequently complicated by the destructive and necrobiotic processes characteristic of this illness. Such processes develop especially often in the vicinity of hemorrhages in the stomach and intestine. Disengagement of the necrotic tissues leads to the formation of ulcers. Similar processes frequently develop in the oral cavity (gums and tonsils).

The symptoms of the hemorrhagic diathesis begin to abate at the end of the second period. In A.V. Kozlova's opinion, the most characteristic pathological changes during this period of radiation sickness are local gangrenous foci (abscesses and gangrene of the lungs and ulcerative colitis) resulting from infection conjoined with the hemorrhages.

The heart is characterized by numerous hemorrhages in the epicardium and myocardium (Fig. 11). The muscle fibers of the heart exhibit signs of protein and fat dystrophy.

The liver. Pathologoanatomical examination of the liver during acute radiation sickness reveals considerable morphological and functional changes which take the form of a disturbance of blood- and lymph-circulation and degeneratively necrobiotic changes in the hepatic parenchyma and stroma. Glycogen disappears from the liver cells and a
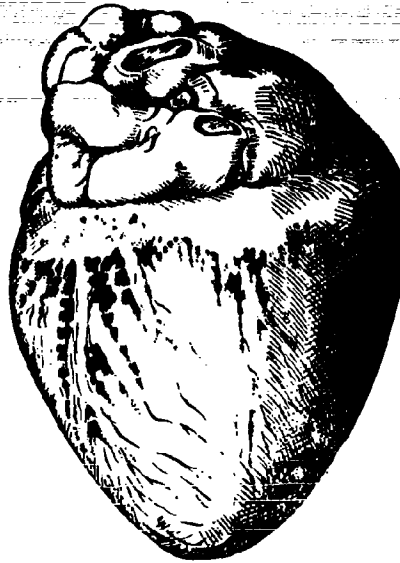
Fig. 11. Hemorrhaging in the
epicardium.

fatty infiltration develops. A.V. Kozlova observed nuclear pyknosis of
the hepatic cells and atrophy of the Kupffer cells during the third
period of radiation sickness. The dystrophic changes which develop in
the liver may ultimately lead to cirrhosis.

The lungs. Emphysema of the lungs is usually observed during the
first period of the illness, while hemorrhages (frequently complicated
by pneumonia) are detected during the second. At the end of the second
or beginning of the third period of radiation sickness infections be-
come associated with the hemorrhagic foci, causing the development of
pulmonary abscesses and gangrene.

The kidneys. At the height of the illness the kidneys exhibit
various degrees of hematuria and dystrophic changes in the epithelium,
the latter being especially marked in the convoluted tubules.

Changes in the endocrine glands are also characteristic.

The adrenal glands. There are very substantial changes in the

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adrenal glands during acute radiation sickness. The adrenal cortex becomes poor in lipoids and atrophies. The cells of the cerebral matter also exhibit a decrease in chromaffin inclusions. Atrophic processes involving connective-tissue proliferation develop in these glands during the later stage of the illness (N.A. Krayevskiy).

The thyroid gland. Phenomena of a dystrophic character are observed in the thyroid gland during acute radiation sickness induced by external irradiation. There is a decrease in follicle size, hypertrophy of the follicular epithelium, and vacuolization and resorption of the intrafollicular colloid.

The gonads. A severe attenuation of spermatogenesis accompanied by damage to the seminific epithelium occurs in the testicles. Atrophy and destruction of the maturing follicles are observed in the ovaries. This damage is caused by the well-known sterilizing action of radiant energy.

Diverse degenerative changes, which are irreversible in the majority of cases, thus occur in all organs and systems under the influence of ionizing radiation.

Remote Sequelae of the Action of Ionizing Radiations

The problem of the remote sequelae of the action of ionizing radiation is not only theoretically interesting, but also practically important. The Soviet literature contains a great deal of data which indicates that very diverse pathological processes develop in the living organism long after injury. Thus, according to the data of A.V. Kozlova, a number of residual symptoms could be observed in the victims of the bombing at Hiroshima after two years. These took the form of general weakness, dizziness, throbbing of the heart, neuralgias, lymphadenitis, enterocolitis, and asthmatic conditions. The victims also exhibited frequent mental disorders, which took the form of loss of memory, a

susceptibility to rapid mental fatigue, and schizophrenia. In addition, those persons subjected to the action of the ionizing radiation manifested a markedly reduced resistance to infection, many of them consequently dying of infectious diseases during the following years.

A.V. Kozlova also noted characteristic leukemias with peculiar courses among the residual phenomena in persons who had recovered from radiation sickness. An aplastic anemia developed first, this being followed by the leukemic syndrome.

These illnesses cannot be treated and the blood never returns to normal. Other authors have also pointed this out.

In studying the composition of human blood long after injury by ionizing radiation, I.K. Petrovich was unable to detect complete normalization; to the contrary, the author observed a prolonged disruption of this composition, the number of erythrocytes being reduced and the leucocyte count undergoing a constant decrease.

Analogous results were obtained by I.P. Usacheva, who studied the remote sequelae of acute radiation sickness in dogs. The animals which survived a massive whole-body irradiation in doses of 600-800 r did not exhibit complete restoration of the hemopoietic function during a two-year period, this indicating:

1) instability of erythropoiesis and thrombopoiesis; 2) relative leucopenia caused by insufficiencies in lymphopoiesis and myelopoiesis. The animals also exhibited instability of nervous-system reactions, baldness, and symptoms of cachexia. V.V. Sokolov studied the remote sequelae of the action of fast neutrons on animals. When he investigated the sexual functioning of dogs two years after irradiation, all of the animals proved to be sterile. No improvement was observed when the investigation was repeated after 3.5 years, the sexual function still not being reestablished.

Ionizing radiation is undoubtedly harmful to the offspring of irradiated animals, there being many indications of this in the literature.

S.P. Voskresenskiy and A.P. Novikova observed the development of the offsprings of dogs exposed to uranium fission products. The authors noted a decrease in the number of embryos in each succeeding litter; a high percentage (more than half) of the puppies were stillborn and there was a high mortality among the newborn animals. The authors believe that one of the important causes of this high mortality was respiratory insufficiency, this being objectively manifested in atelectasis of the pulmonary tissue. It was also found that the formation of organs (lungs, heart, liver) lagged behind that proper to their age level in these animals.

Observing these puppies further, the investigators noted a marked lagging in weight and growth and a decrease in resistance to the influence of environmental factors; some of the animals died of infectious diseases. Certain authors also believe that the offspring of irradiated animals are characterized by functional disturbances involving the central nervous system, these taking the form of increased excitability and reactivity. Many years of observation of the offspring of irradiated mothers has shown that they age prematurely and have a shortened life span. Plummer obtained very interesting and indicative data when he examined several hundred children from the city of Hiroshima.

The author noted a high percentage of deformities and stillbirths and a high mortality among newborns many years later in the offspring of persons injured by radioactive substances and external irradiation. The newborns exhibited an extremely low resistance to environmental factors and died of infections, helminthiasis, and toxic dyspepsia.

Ionizing radiation also has a destructive influence on the visual organs; when an organism is exposed to fast neutrons cataracts develop long after injury, leading to complete blindness. According to the data of A.V. Kozlova, 18.9% of the children born to parents injured in the bombing had congenital deformities. The author cites the interesting results of pathologoanatomical examinations of 700 newborns (predominantly stillbirths or infants which died during the first few days after birth). 11% exhibited severe congenital deformities which rendered them unviable; these included lack of a brain, hydrocephaly, lack of an anus, congenital lack of bones, etc.

Imperfections in the development of the cardiovascular system and the bone-muscle apparatus predominated among the anomalies.

The offspring of parents exposed to ionizing radiation are thus little fitted for survival.

The remote sequelae which occur when radioactive substances enter the body are still more dangerous. In contrast to external irradiation, these substances are a source of continuous irradiation, occasionally for many years. Once in the body they are subject to various chemical transformations, but this does not alter their radioactive properties at all.

V.N. Strel'tsova and Yu.I. Moskalev studied the remote sequelae of introduction of the radioactive isotopes Ce^{144}, Ru^{100}, and Sr^{90} into the body. These investigations revealed the following mechanisms: introduction of Ce^{144}, which is absorbed primarily by the liver, into the body led to the gradual development of tumors in the gastrointestinal tract, mammary and endocrine glands, and liver.

Introduction of Ru^{100} into the body caused the development of ulcerative processes in the large intestine, periarteritis, neurosclerosis, and soft-tissue tumors. When Sr^{90} was introduced into the body,

it was selectively and persistently deposited in the skeleton, this causing substantial functional changes in bony tissue accompanied by the development (occasionally over a period of many years) of osteogenic sarcomae. Development of leucoses is one of the remote sequelae of introduction of radioactive strontium into the body.

Thus, when radioactive substances enter the body they are retained for a prolonged period and form a constantly acting radiation focus. L. Prosser has pointed out that it is possible for malignant tumors to develop in persons working with radium 8-10 years after contact begins. All this necessitates attentive and careful handling of any source of ionizing radiation.

Since radioactive isotopes have come into use in medicine and industry, scientifically proven protective measures must be put into practice in work with radioactive isotopes.

Prophylaxis of Radiation Sickness

The experimental investigations of recent years have to a considerable extent clarified the biological action of ionizing radiation; in this connection methods of protecting the living organism from ionizing radiations have been proposed. These include many prophylactic measures. Among the numerous prophylactic measures suggested by both foreign and Soviet authors, organic sodium-containing compounds (cysteine, glutathione, and β-mercaptoethylamine) warrant our attention. Experimental data (Smit and Patt) have shown that intravenous injection of a cysteine solution 5 minutes before irradiation has a marked protective effect. Precisely the same is true of glutathione (see the works of Ye.P. Kronkayt and his colleagues), which considerably reduces mortality among irradiated animals when administered several minutes before irradiation. The author gave the animals a subcutaneous injection of 4 mg/kg of a 10% glutathione solution. It must also be noted

that one of the important properties of glutathione is its ability to accelerate the regeneration of hematogenic organs injured during irradiation. Both Soviet (S.Ya. Arbuzov, I.I. Barashnikov, G.T. Chernenko) and foreign authors (Z.M. Bak) have now pointed out the good protective properties of β-mercaptoethylamine. In the opinion of the aforementioned investigators, this compound is of low toxicity and is an extremely effective preparation with respect to protective action in the presence of radiation injuries. According to the data of Bak et al., a single intravenous injection of 200 mg of β-mercaptoethylamine prevents the symptoms of radiation sickness. However, interesting new indications of the still greater protective effect of a combination of adrenaline and acetylcholine have recently appeared in the Soviet literature (see the works of L.F. Semenov and Ye.P. Prokudina). Subcutaneous injection of these drugs immediately after irradiation led to survival of 35% of the animals so treated, 100% of those in the control group dying.

The protective effect of this combination of adrenaline and acetylcholine took the form of attenuation of the symptoms of radiation sickness, acceleration of the functional restoration of the hematogenic system, and reduction of the affection of the small intestine. Comparing the action of this combination with the effectiveness of the best-known protective compounds, the authors obtained interesting data. Thus, administration of cysteine produced a total of 10% survival, β-mercaptoethylamine led to 15% survival, thiourea produced 20% survival, and a combination of adrenaline and acetylcholine produced 35% survival, i.e., the highest survival rate. Sodium salicylate is also a drug which reduces the effects of ionizing radiation.

According to the observations of N. Beu, intraperitoneal injection of sodium salicylate in a dose of 500 mg/kg for a week before ir-

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radiation sharply reduces the mortality among irradiated animals (to 50%, as against 100% in the control group).

Narcotics are also drugs which protect against penetrating radiation. Mortality is lower among animals which receive morphine before irradiation than in the control group. Barbiturates have a very marked protective effect.

Prophylactic measures also include sufficient protein in the diet of irradiated individuals, since protein starvation heightens the sensitivity of animals to ionizing radiation and increases mortality after irradiation. Certain Soviet authors (I.I. Ivanov, V.S. Balabukha, et al.) recommend that nitrogen be supplied parenterally in order to prevent the development of a negative protein balance after irradiation. Various preparations of protein hydrolysates are used for this purpose. However, as experimental and clinical data have shown, internal administration of these preparations is unwise, since both digestion and protein assimilation are disrupted in the presence of acute radiation affections. Injection of protein hydrolysates directly into the bloodstream has the desired effect.

In connection with the disruption of carbohydrate metabolism in irradiated animals, which is characterized by instability of the blood sugar content, certain authors recommend that an artificial hyperglycemia be set up before irradiation as a prophylactic measure, this reducing the mortality among irradiated animals.

In order to prevent the increased vascular-wall permeability and fragility which occurs after irradiation, Sokolov recommends preliminary administration of vitamin P in the food (the experimental animals receiving lemons for 30 days before irradiation). Such enrichment of the body with vitamin P reduces mortality by 10%.

Antibiotics are employed prophylactically to prevent the develop-

ment of bacteriemia. The lowest mortality among irradiated animals is observed when they are given streptomycin. Pathologoanatomical examination showed that dogs which received antibiotics exhibited less marked hemorrhagic phenomena, ulcerations of the intestine almost never being encountered.

The protective properties of certain hormones warrant mention. According to the observations of K.V. Taber, adrenocorticotropic hormone halts the radiation reaction and has no side effects. In the opinion of certain foreign authors (Ye. Valdonio and G. Kallidari) adrenal cortex extract (cortigen B) alleviates the radiation reaction and reduces nausea and vomiting.

All protective drugs may thus provisionally be classified into those which slow down the radiochemical reactions and those which reduce the radiosensitivity of the organism. Despite the wealth of drugs suggested, completely reliable prophylactic measures have still not been found.

Prognosis of Radiation Sickness

The prognosis of radiation sickness depends on the dose and penetrating power of the type of radiation in question. The distance between the victim and the blast site is also of great importance. According to the data of A.V. Kozlova, persons no farther than one kilometer from the epicenter died. Victims at a distance of two kilometers developed acute radiation sickness with a mortality of 50%. Mortality was highest among children and the elderly. The lethality of radiation sickness also increases when burns, wounds, and secondary infection are present. The general reactivity of the organism also plays a large role. Any manifestation of insufficiency and enervation of the central nervous system during acute radiation sickness thus indicates an unfavorable prognosis. Among the laboratory data, a sharp drop in leuco-

cyte count points to a poor prognosis. When the number of leucocytes drops below 100 per mm^3 the patient usually dies. The sedimentation rate is also of prognostic importance. Death frequently occurs when the sedimentation rate is from 60 to 90 mm per hour.

First Aid and Treatment of Acute Radiation Sickness

Acute radiation sickness is treated during two stages of medical evacuation: during the first stage, in the region of the catastrophy, self-help and mutual aid are given and medical aid is rendered by first-aid stations and health forces. Emergency medical aid is given at the OPM, as well as in other surviving medical institutions; during the second stage specialized aid and treatment is completely handled by suburban hospitals equipped for this purpose.

The basic principle of the treatment of acute radiation sickness is complex therapy conducted in accordance with the clinical course of the illness and the individual characteristics of the victim. Early application of all possible therapeutic measures moderates the subsequent course of the illness and prevents complications.

In prescribing drugs it is necessary to take into account the altered sensitivity of patients with radiation sickness. This change may take the form of either an increase or decrease in sensitivity. The treatment must correspond to the period of the illness. During the initial and latent periods measures must be taken in the OPM as far as possible. The victim must be moved to a fully equipped hospital at the beginning of the period of marked clinical symptoms.

The complex of therapeutic measures is successively put into effect during both stages of evacuation.

First stage. Medical first aid. Exposure to radiation is frequently conjoined with mechanical traumas, burns, and other injuries. Self-help, mutual aid, and first aid rendered by aid stations and

health workers are given in the focus of injury.

In mild and moderately severe radiation sickness the victims' general condition remains satisfactory for the first few hours after irradiation. Even when the symptoms of the first period of radiation sickness appear patients are able to go to the OPM under their own power. In the severe and extremely severe forms of the illness the victims should be transported on litters as far as possible, since walking or any other physical stress complicates the course of the illness.

No matter what the severity of their illness, all of the victims pass through the admitting and classifying section of the OPM, which is equipped with radiological monitoring equipment; here they are divided into two groups: 1) those contaminated with radioactive substances and 2) uncontaminated persons.

As far as possible, these two groups are given medical aid in different areas.

When the radiation injury results only from external irradiation its severity is determined by the clinical course of the illness, the readings on personal dosimeters, and data furnished by radiological surveys.

Victims with a mild form of radiation sickness who exhibit no symptoms do not require hospital treatment and can be moved later. When excitation, insomnia, tremors, and disturbances of cardiac activity appear in the victims they are given cardiac stimulants (strophantin, camphor, and cordiamine), sedatives (barbamyl, bromine, and pantopon), and other drugs. The nausea and vomiting are alleviated by gastric lavage. Administration of a physiological salt solution and a 5% glucose solution parenterally is indicated in cases of uncontrollable vomiting and diarrhea. Penicillin is given in a dose of 100,000

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to 200,000 units for prophylactic purposes.

Sedatives (pantopon, barbamyl, bromine, and valerian) are prescribed for all victims before further transportation, even when there are no marked symptoms of illness.

Second stage. Specialized medical care. In the specially equipped suburban hospitals the patients receive specialized medical aid and comprehensive specialized treatment is carried out. The initial measures in this treatment will depend on the amount of aid rendered at the OPM, the period of illness, and the individual characteristics of the victim.

The treatment of acute radiation sickness may be classified into the following measures:

I. During the initial and latent periods:

1) physical and mental rest — a rigid bedrest regime;

2) a rational diet;

3) careful treatment of the skin and mucosa;

4) prescription of sedatives during the period of excitation;

5) administration of cardiac stimulants when cardiovascular insufficiency is present;

6) early and prolonged use of antibiotics and sulfamide preparations;

7) measures to prevent dehydration and symptoms of intoxication;

8) administration of dimedrol and other desensitizing drugs;

9) measures to reduce the nausea, vomiting, headache, and other symptoms of the illness.

II. It is recommended that the following measures be taken during the height of radiation sickness, in addition to those put into effect during the initial and latent periods:

1) transfusion of blood and liquid blood substitutes;

2) transfusion of a leucocyte mass and prescription of drugs which stimulate bone-marrow activity and cause a leucocytic reaction;

3) prescription of hemostatic drugs and those which reduce the permeability of the vascular walls;

4) administration of drugs which increase the immunobiological resistance of the organism (Acad. Bogomol'ts' ATsS, Filatov's tissue therapy, etc.);

5) hormonal preparations.

III. It is recommended that the following measures be taken during the resolution period of radiation sickness in addition to those put into effect during the preceding periods:

1) administration of drugs which stimulate hematogenesis;

2) blood transfusions;

3) broadening of the diet to produce increased nutritional value;

4) therapeutic exercise;

5) prescribed walks;

6) physical therapy.

Treatment during the initial and latent periods. Physical and mental rest are necessary throughout the entire course of treatment. Bed rest from the beginning of the illness until the recovery period is necessary for patients with moderate and severe forms of acute radiation sickness.

Considering the tendency of the patients to hypothermia, the temperature in the ward should be kept at approximately 18-20°. Just as excessive cooling, overheating of the victim has an unfavorable influence on the course of his illness. During the period of excitation it is desirable to darken the victim's room and isolate him from noise and other stimuli as far as possible.

The patient is best seated while vomiting. When the patient is in

serious condition his head is turned to the side and care is taken that the vomitus does not flow into the respiratory passages. After vomiting the patient is given a weak solution of boric acid or soda with which to rinse his mouth. When the patient is in serious condition his mouth is washed out with solution from a rubber bulb or Esmarch jar.

Rational nutrition is based on the principle of a mechanically and thermally sparing diet.

The patient's food should be liquid or of a gruel-like consistency, coarse and irritating substances being excluded; it should be given in small portions 5-6 times a day. As far as its thermal character is concerned, the diet should be high in calories, rich in proteins and vitamins, and easily assimilable. Soups and purees of groats and vegetables, eggs, meat pies of liver and ground meat, thin porridges of various grains, cooked fish, pot cheese, dry white bread, fruit jellies, and compotes are recommended. Therapeutic preference among food products must be given to curdled milk, sour milk, and kefir. R.S. Mostova, A.M. Yugenburg, and others recommend the use of acidophilous soured milk, this having an especially favorable action on the intestinal flora in their opinion.

As for beverages, it is wisest to prescribe fruit, berry, and vegetable juices, sweetened tea with milk, and mineral water. If it is impossible to administer vitamins in the food, polyvitamins are prescribed.

When the patient is unconscious nutritive substances are administered in enemas, as well as by intravenous and subcutaneous infusion of glucose and protein-containing liquids. When there is gastrointestinal bleeding the diet must be especially rigid, food being given in small portions every three hours. Only liquid food (ice cream, milk,

soft-boiled eggs, and thick soups) are given until the bleeding ceases. It is important to make sure that the intestine functions normally. Belladonna and laxatives (rhubarb, purgatin, and mineral oil) are prescribed during the first few days of spastic constipation.

Either gastric juice or a solution of hydrochloric acid containing pepsin and pancreatin is prescribed to increase the patient's appetite and normalize his digestion.

Care of the skin and mucosa is carried out for prophylactic purposes from the beginning of the illness.

Considering the reduced trophics and heightened sensitivity of the dermal tegmina and mucous membranes, it is necessary to avoid all traumatic factors. In the presence of infections the slightest injury, brushing the teeth with a toothbrush, or the use of hot-water bottles or ice bags can disrupt the integrity of the tegmina and permit the entry of infection.

Dry skin is smeared with neutral fats or creams to moisten it. Measures to prevent bedsores are taken during the first few days of illness when the patient is in serious condition. The hair falls out during radiation sickness. Special attention must be paid to oral hygiene. It is wise to keep the oral cavity clean during the latent period of the illness in order to eliminate additional sources of infection. The mouth is rinsed with disinfectant solutions (boric acid, rivanol, potassium permanganate) before and after each meal. After eating the interproximal spaces are cleaned with a cotton ball moistened with a 3% hydrogen peroxide solution and the mouth is again rinsed. In the seriously ill the oral cavity is rinsed with solution from a Esmarch jar equipped with a long rubber tube bearing a glass tip. When ulcerations are present cotton pads moistened with antibiotic solutions (biomycin, penicillin, furacillin, germicidin, sanazine) are applied

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to them after the mouth is washed out. In addition, it is recommended that the ulcers be smeared with a 1% solution of methylene blue in 40% glucose once a day (after dinner).

Sedatives are prescribed when the patient is in an excited state. The patient must be ensured rest at the beginning of the illness, bromides or convallaria and valerian being prescribed. When the excitation and insomnia are very marked barbiturates, promedol, and morphine are administered in ordinary therapeutic doses, the individual characteristics of the victim being taken into account. However, prolonged use of soporifics is unwise, especially in cases of severe injury.

Aminazine has an especially favorable sedative action. In addition to reducing respiratory activity and having a soporific and soothing effect it is able to halt vomiting and hiccuping. A large dose of the drug, up to 0.4 g, is prescribed to end the acute excitation and it is then administered in moderate doses (single doses of 0.025-0.05 g and a daily dose of 0.1-0.3 g).

It is necessary to take into account the fact that, when used in conjunction with other narcotics, soporifics, analgesics and antispasmodics, aminazine intensifies their action.

Cardiac stimulants (caffeine, camphor, cordiamine, strophanthin, etc.) are prescribed only when cardiac activity is disrupted. Just as the other drugs, cardiac stimulants are administered internally in ordinary doses as far as possible. When the illness is conjoined with angina pectoris, validol or a nitroglycerine solution is prescribed first and the cardiac stimulants are then administered. Any considerable drop in arterial pressure requires immediate subcutaneous injection of caffeine and camphor.

Antibiotics are used for prophylactic purposes from the moment when the victim comes under a doctor's care. Penicillin is administered

prophylactically in doses of 300,000-400,000 units once a day or every other day, the dosage being increased to 2-3 million units per day for therapeutic purposes. It must be kept in mind that the site of an injection may serve as an infection atrium. It is consequently wise to use novocillin, bicillin, and other long-acting antibiotic preparations, which reduce the number of injections. Administration of bicillin has the advantage of making use of the marked antihistamine action of this drug. Phenoxymethyl penicillin (a penicillin preparation) is prescribed for internal administration for prophylactic purposes. Considering the fact that infectious complications may be caused by a combination of several species of microorganisms, V.L. Troitskiy, R.V. Petrov, V.D. Rogozkin, and other authors recommend that antibiotics with different spectra of action be used jointly; no less than two antibiotics should be administered simultaneously. When antibiotics are used for a prolonged period the bacteria may become resistant and side effects may develop; this is avoided by changing the antibiotics every 4-5 days.

Terramycin, levomycin, and synthomycin are most effective in treating intestinal infection. Synthomycin, aureomycin, and levomycin are prescribed for infections caused by gram-negative bacteria. Because of the tendency of patients with radiation sickness to develop stomatitis biomycin must be prescribed with great care, since it occasionally causes stomatitis by itself and can aggravate an existing process.

P.D. Gorizontov, N.V. Rayeva, and others have shown the effectiveness of oral administration of antibiotics for radiation injuries. When antibiotics are administered orally and by inhalation their concentration in the sites of microorganism accumulation is increased. However, this method of administering antibiotics does not maintain the requisite concentration in the blood and they are consequently ad-

ministered intramuscularly as well as by inhalation or orally. When two antibiotics are given simultaneously one of them is administered internally and the other intramuscularly. N.V. Rayeva, M.N. Fedotova, and other authors recommend that antibiotics be used in conjunction with antihistamines, antihemorrhagics, and vitamins (dimedrol, citrin, and vitamins of the C, B, and PP groups) in order to avoid undesirable side effects.

Sulfamide drugs should be prescribed early in the illness, in combination with antibiotics; it is recommended that phthalazole be administered internally only in cases of diarrhea.

Considering the ability of sulfamide preparations to intensify leucopenia, the morphological composition of the blood must be monitored with especial care when they are used.

Detoxication measures are intended to prevent the intoxication of the organism which manifests itself during the first period of radiation sickness. One important therapeutic measure is phlebotomy followed by blood replacement. As P.D. Gorizontov has shown, this measure is effective when carried out 1-3 times no more than three days after irradiation, approximately 10-30% of the circulating blood (400-600 ml) being let. Phlebotomy and blood replacement on the 5th day of illness or later aggravates the course of the sickness. Both citrated blood and polyglucin (preparation L-103) can be used as blood substitutes. Such blood replacement has the same effect as massive blood transfusions (P.D. Gorizontov).

In order to avoid tissue dehydration and to maintain the water-salt equilibrium, up to 2 liters of physiological solution and a 5% glucose solution or a special salt infusion are administered subcutaneously. G.A. Levchuk and V.Ya. Lavrik recommend that an infusion of BK-8, the hydrolysate TsOLIPK, and L-103 be given when the liver is

damaged. In the opinion of these authors, in addition to their detoxi-
cating influence, blood substitute solutions aid the organism in pre-
venting hypoproteinemia and serve as parenteral nourishment. Infusions
of polyglucin, aminopeptides, and protein hydrolysates are especially
effective.

Low-molecular-weight polyvinyl pyrrolidine preparations (periston)
have good detoxicating properties. They are infused in doses of 250 to
500 ml daily during the first three days, depending on the severity of
the toxicosis (A.V. Kozlova).

A.A. Bagdasarov recommends the use of transfusions of protein so-
lution No. 1, which not only have a favorable effect on the detoxica-
tion of the organism and the normalization of metabolic processes, but
also prevent the development of hemorrhages, early erythrocyte hemo-
lysis, and hypotonia. Transfusions of this solution are easier but no
less effective than blood transfusions; they are given daily in a dose
of 200-250 ml for the first three days, then every other day until a
total of 6-7 transfusions have been administered. This solution is not
subsequently administered in order to avoid hives, edemas, and other
allergic reactions.

Dimedrol has a nonspecific desensitizing action. It reduces the
smooth-muscle spasms caused by histamines, has a sedative, soporific,
and antiemetic effect, and strengthens the vascular walls.

Dimedrol's therapeutic effect on radiation sickness takes the
form of a decrease in dyspeptic disturbances, a retardation of loss of
weight, a decrease in leucocyte count and arterial pressure, and a re-
duction of the manifestations of toxicosis and the hemorrhagic syn-
drome. It is administered internally in a dose of 0.03-0.05 g one to
three times a day. Because dimedrol depresses the secretory function
of the stomach it is wise to administer it two hours before or two

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hours after eating. When this timing is used the inhibiting influence of the drug on gastric secretion has already ceased by meal-time.

When necessary dimedrol is administered intramuscularly and intravenously as a 1-2% solution. When injected intravenously the drug is dissolved in 75-100 ml of an isotonic sodium chloride solution and administered by the drop method. The course of treatment lasts approximately 10-15 days. Dimedrol is most effectively used in conjunction with pyridoxine and nicotinic acid, which are administered internally in doses of 0.02-0.05 g 2-3 days a day. If it is impossible to take nicotinic acid internally, it is administered intravenously and intramuscularly in the form of a 1% solution. Pyridoxine is produced in ampoules containing 1-2.5 g and as a 5% solution, the requisite quantity being administered intramuscularly.

Symptomatic measures. When persistent nausea and vomiting are present, it is wise to administer a hypertonic sodium chloride solution and prescribe aeron and phenocoll.

When respiration is depressed or arrested it is necessary to administer carbogen, atropine, caffeine, camphor, and other drugs in ordinary doses; lobeline and cytitone usually have a negative effect and their use is contraindicated. Severe headaches are relieved by pyramidon, analgin, and phenacetin.

Treatment during the height of radiation sickness

Transfusions of leucocyte mass are given when a severe progressive leucopenia is present. Introduction of leucocytes into the blood stream has both a substitutional and stimulating effect. Considering the importance of leucocytes in the protective functions of the organism, their ability for phagocytosis, and their part in the production and transportation of immune bodies, A.A. Bagdasarov recommends repeated intravenous transfusions of leucocyte mass (every 2-3 days in a dose of 1.5 million leucocytes until 8-9 transfusions have been given).

Drugs which stimulate bone-marrow activity and cause a leucocytic

reaction are prescribed for less marked leucopenia. Sodium nucleid is administered internally in a dose of 0.1-0.2 g three times a day or intramuscularly in a dose of 5-10 ml of 2-5% solution for this purpose. The course of treatment lasts 10-12 days. In order to intensify the action of this drug it is administered in conjunction with pentoxyl or the latter is administered alone in a dose of 0.2-0.3 g of No. 1 powder three times a day.

Tezan is also a leucopoietic stimulator, being administered internally in a dose of 0.01-0.02 g 3-4 times a day or intramuscularly as a 0.1-0.5% solution; it may also be administered in drops (a 0.5% solution in 20% alcohol), 10-15 drops being taken on eating. Leucogen has an action analogous to that of tezan and is administered internally in a dose of 0.02 g 3-4 times a day.

Hemostatic drugs. The hemorrhagic syndrome is basically distinguished by three factors: disruption of the permeability of the vascular walls, an increase in the fragility of these walls, prolongation of blood-clotting time, and thrombocytopenia.

Therapeutic measures must consequently be aimed at these phenomena. The permeability of the vascular walls is reduced by prescribing intravenous injections of calcium chloride in a dose of 10 ml of 10% solution and rutin, which has the ability to reduce the brittleness and permeability of capillaries, in a dose of 0.02 g three times a day. The latter drug should be given in conjunction with ascorbic acid, since vitamin C not only has a hemostatic effect, but is also a synergist of rutin. Vitamin P (citrin) is administered in analogous fashion to rutin, in a dose of 0.05-0.1 g three times a day. Vicasol, a preparation of vitamin K, is administered in order to improve blood clotting (internally in a dose of 0.01 g 2-3 times a day or intramuscularly in a dose of 3-5 ml of 0.3% solution).

A.A. Bagdasarov and others recommend transfusions of thrombocyte mass to reduce the thrombopenia.

Drugs which increase immunobiological resistance are prescribed for anergy.

A.I. Smirnova-Zamkova, P.Ya. Sologub, and others have shown that early administration of stimulatory doses of ATsS [ACS] to irradiated dogs reduces the extent of the dystrophic changes and hemorrhagic syndrome, as well as stimulating regenerative processes in the lymphoid and hematogenic tissue.

Filatov's tissue therapy (for the vitreous body) is recommended when protracted trophic disturbances are present.

A combination of small doses of bromine with caffeine, sodium benzoate, and strychnine nitrate has the most favorable effect in the functional restoration of the nervous system. The administration of strychnine should be periodic in order to prevent any possible cumulative effect.

Intravenous or intramuscular injections of small quantities of long-stored isogenic banked blood has a stimulating effect.

Hormonal preparations are prescribed for numerous hormonal disturbances. Deoxycorticosterone, adrenocorticotropic, pituitary hormone, and other hormonal preparations are administered in ordinary doses. However, they must be used with caution. This problem is still being studied further.

Treatment during the recovery period

During the recovery period the therapeutic measures employed during the prior clinical periods are used only when necessary. Hematogenic stimulators should be widely used during this period.

Blood transfusions. A.A. Bagdasarov, N.A. Kurshakov, A.K. Gus'kova, and others believe that transfusions of whole blood and its com-

ponents are effective in acute radiation sickness. Such transfusions are especially necessary in the extremely severe and severe forms of the illness. When shock, hemorrhaging, wounds, or burns are present blood transfusions are indicated for all forms of radiation sickness.

P.D. Gorizontov and V.D. Rogozkin note the great effectiveness of transfusions of whole blood and erythrocyte mass during the recovery period. According to A.A. Bagdasarov, transfusions of citrated blood begun on the 4th-5th day after irradiation intensify erythrocyte decomposition and aggravate symptoms of a hemorrhagic diathesis. Transfusions of citrated blood are consequently contraindicated from the 4th to the 15th day and transfusions of fresh and dry plasma are substituted when necessary.

During the period of greatest depletion of the hematogenic system transfusions of whole blood may act as an extreme stimulus and cause a negative reaction. Transfusions of whole blood and erythrocyte mass in large quantities are consequently contraindicated during the latent period and height of the illness. Blood transfusions are prescribed in accordance with the clinical course and period of the illness. Whole blood is best prescribed in doses of 3-7.5 ml per kg of body weight, while erythrocyte mass and plasma should be administered in doses of 0.5-2 ml per kg of body weight.

When shock, hemorrhaging, wounds, or burns are present transfusions of whole blood (200-400 ml) or erythrocyte mass (100-120 ml per transfusion are prescribed during the initial period. The transfusions are given dropwise and should obey all of the rules for such operations (M.N. Pobedinskiy, N.A. Kurshakov).

As P.D. Gorizontov has shown, a temporary change in blood compatibility may occur after irradiation (especially when large doses are received); the cross-compatibility of the blood of the irradiated re-

cipient and that of the donor is consequently tested before each trans-
fusion. Undesirable post-transfusion reactions frequently occur in ir-
radiated persons even when the blood is compatible. P.D. Gorizontov
and V.D. Rogozkin recommend that small quantities (20-30 ml) of the
compatible blood to be transfused or 5-6 ml of a 1% dimedrol solution
first be administered intravenously together with glucose and ascorbic
acid in order to reduce these reactions.

Hematogenic stimulators are prescribed in conjunction with blood-
substitutes and have the greatest effect during the fourth period.

At the beginning of the illness, during the period of brief over-
stimulation of the hematogenic system, the use of hemostimulators is
contraindicated in order to avoid further overexcitation.

Intravenous injection of suspensions of bone-marrow tissue and
intraperitoneal injections of spleen tissue have a beneficial influ-
ence on the organism (N.A. Kurshakov).

Antianemine, which is administered intramuscularly in a dose of
2-4 ml once a day until the hemoglobin count increases, yields espe-
cially favorable results. Kampolon, a similar drug, is administered in
a dose of 2-4 ml daily or every other day. When there is no vomiting
liver extracts are administered internally in a dose of 1 teaspoon 3-4
times a day. Vitamin B_{12}, a drug which has a marked hemopoietic action,
is prepared from liver extracts. This vitamin is produced in ampoules
containing 30, 100, 500, and 1000 µg per ml of preparation. It is ad-
ministered in doses of 1 ml subcutaneously or intramuscularly. The
frequency of injection and the total quantity of the drug administered
depends on the morphological composition of the blood. Vitamin B_{12} is
given both as a hematogenic stimulator and as a nuclein-metabolism
stimulator. The action of vitamin B_{12} is intensified when folic acid
is given in a dose of 0.02-0.04 mg. Only preparations of iron and

hematogens should be administered in mild forms of anemia.

Chapter 4

COMBINED RADIATION INJURIES

General Characteristics of Combined Injuries

In an atomic blast individuals are subjected to the simultaneous
action of several injurious factors. This results in the occurrence of
combined injuries: a combination of radiation sickness with burns,
wounds, and other traumas. These injuries may take their course against
a background of radiation sickness caused by external and internal ir-
radiation.

B.M. Khromov recommends that all combined radiation injuries be
divided into two classes: 1) combinations of any mechanical or thermal
trauma with radiation sickness, but without contamination of the wound
surface by radioactive substances; 2) "mixed radioactive injuries," in
which the wound surface is contaminated with radioactive substances.

It is well known that the general and local resistance of the
body decreases, hematogenesis and the phagocytic activity of the leuco-
cytes is depressed, bleeding develops, tissue regeneration slows down
greatly or ceases, protein and other forms of metabolism is disrupted,
and avitaminosis develops during radiation sickness. Ionizing radia-
tion causes various degenerative necrobiotic and necrotic processes in
cells and tissues and the reproductive capacity of the cells of vari-
ous tissues is somewhat reduced, i.e., the capacity for tissue regen-
eration is decreased (B.M. Khromov). Under these conditions the resist-
ance of the body to trauma is reduced and the usual course of the lat-
ter is altered. Even a slight injury can develop into a serious proc-

ess which wears the patient out.

The aggravating effect which radiation sickness and wounds have on one another greatly intensifies the necrotic processes. Necroses and other complications most frequently set in during the period of marked clinical symptoms of radiation sickness. The combined action of traumas and ionizing radiation leads to a severe affection, even when each factor is not in itself sufficiently severe to cause serious damage to tissue or the entire body.

Wounds and burns are easily infected and shock, collapse, sepsis, and other complications frequently set in. The healing of wounds and burns or the knitting of fractures is rather slow against a background of radiation sickness, proceeding with numerous complications. Traumas complicate the course of radiation sickness, while the latter retards and impairs the processes which act toward the restoration of any traumatic injury. The "symptom or syndrome of mutual aggravation" develops.

Combined injuries are treated in accordance with the general scheme of successive step-by-step treatment; in the first stage of medical evacuation (in the OPM or hospitals which have been spared) first aid is rendered in accordance with vital indications. The treatment given here includes administration of sera and antibiotics and application of aseptic dressings. As far as operations at the OPM are concerned, surgical interventions are performed only when vital indications so require (hemostasis, tracheotomy, suturation of the open pneumothorax, amputation of limbs, etc.) and wounds and other injuries contaminated with radioactive substances are surgically treated. Radical surgical treatment is performed during the second stage (in special suburban hospitals). In addition to local surgical treatment of wounds, attempts are made to prevent shock, intoxication, infection, and bleed-

ing, radiation sickness is treated in complex fashion, and measures are taken to eliminate radioactive substances which have entered the body.

Considering the fact that increased bleeding appears in the presence of radiation injuries between the third and tenth days after irradiation, B.M. Khromov draws the following conclusions: 1) all operative interventions in patients with combined radiation injuries should as far as possible be performed before symptoms of radiation sickness, particularly bleeding, appear; 2) when later operative intervention is necessary special attention must be paid to preventing bleeding and even slight hemorrhaging must be carefully staunched.

The amount of antitetanus serum ordinarily administered for any trauma must be increased by a factor of 2-3 in the presence of combined injuries (R.V. Petrov, P.N. Kiselev). Antigangrene sera are also more effective in increased dosages and in combination with antibiotics. According to the investigations of Ye.M. Karpova, 5-7 times as much antitoxin is required to treat gas gangrene during acute radiation sickness than under ordinary conditions.

B.M. Khromov, A.N. Berkutov, and others emphasize the necessity of stimulating regenerative processes in order to accelerate the healing of wounds, burns, and fractures. Dressings of vitamin-containing ointments, Vishnevskiy's ointment, novocaine blocks, tissue transplants, physical therapy, repeated transfusions of small doses of blood or its components (erythrocyte or leucocyte masses), and prevention of anemia and avitaminosis are recommended for this purpose.

In this case it is very important not to overburden the patient with numerous drugs and procedures and to take into account the stage and characteristics of the course of the radiation injury and the wound (B.M. Khromov).

Rational complex treatment conducted in accordance with the clin-

ical course of the illness and the individual characteristics of the victim increases the number of favorable outcomes of combined injuries.

Wounds

In an atomic bombing wounds are inflicted primarily by secondary projectiles (fragments of buildings, pieces of glass, and other objects). They may be limited to soft-tissue damage or accompanied by bone fractures and damage to internal organs, blood vessels, and nerves.

Wounds may be contaminated with sand, dirt, scraps of clothing, and radioactive substances (the latter are described in Chapters 2 and 5).

Primary treatment of wounds and operative intervention in casualties with radiation sickness should be performed as soon as possible, before the period of marked clinical symptoms begins. Antishock drugs must be administered during the primary surgical treatment of wounds, which is carried out by ordinary surgical methods under both local and general anesthesia. In all cases where depression of the respiratory center occurs (chest wounds, pulmonary edema, anoxia, etc.), morphine is contraindicated or should be used with care. When there are massive injuries and a shortage of experienced anesthetists, T. Sirs (on the basis of experience in Japan) feels that ether is the least dangerous anesthetic, an exception being cases of penetrating thoracic wounds, where ether anesthesia is contraindicated.

I.Ya. Tikhonin, I.S. Kas'yanov, and others note that novocaine blocking of the solar plexus and splanchnic nerves in conjunction with infiltration anesthesia by Vishnevskiy's method makes it possible to perform experimental operations during various stages of radiation sickness and produces considerably fewer complications than ether anesthesia when there are multiple body wounds involving gastric and intestinal resection.

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Healing of wounds by direct union is the most favorable. It is especially important that the healing time of wounds be reduced in the presence of combined injuries and that healing be completed before the height of the illness sets in.

Administration of antibiotics and sera at the OPM prevents the development of wound infections. All wounds should be tightly sutured after surgical treatment and administration of antibiotics. Secondary treatment is carried out when a treated wound suppurates and the sutures open.

Suturation of wounds is contraindicated in the following cases:

1) when it is impossible to remove all of the nonviable tissue;

2) when subsequent emergency evacuation is necessary;

3) during the third period of acute radiation sickness;

4) when the wound has not been completely freed of radioactive substances;

5) when there are symptoms of anaerobic and other infections.

N.V. Belokonskaya notes the following characteristics of the course of wounds during radiation sickness: a) a wider zone of traumatic muscle necrosis is formed and it persists for a longer time in the wound; b) the leucocytic demarcation line between the healthy and damaged muscles develops later and is less marked; c) there are hemodynamic disturbances in the vicinity of the wound (plethora of the vessels, more marked tissue edema during the first few days, petechial and grosser hemorrhages during the first two weeks); d) there is a retardation of muscle-tissue regeneration. The hemorrhaging and reduced tissue regeneration promote the development of secondary infection. Leucopenia results from the areactive condition of the body, even when there are suppurative-septic complications; the typical clinical picture does not develop.

Early local and parenteral administration of antibiotics (penicillin, biomycin, streptomycin) at the time of the initial surgical treatment is recommended to prevent suppurative-septic complications.

Streptomycin administered immediately after treatment of a wound and for the next nine days promotes healing by direct union. All that has been said above applies to the treatment of combined injuries before the third period of acute radiation sickness begins. However, we do not mean to exclude cases of surgical intervention during the actual height of the illness. Such intervention is usually performed in accordance with vital indications and is more complex and more difficult. A.N. Berkutov recommends the following precautions in such cases:

1. Blood transfusions on the day before the operation and during it.

2. Administration of drugs which intensify blood clotting (calcium chloride, vitamin B_{12}, vitamin K).

3. Reducing the operating time and the extent of the surgical intervention as far as possible.

4. Continuous presence of hemostatic drugs in the body during the operation, this being necessitated by the increased tissue bleeding which occurs during radiation sickness.

It is also necessary to take into account the fact that patients with radiation sickness withstand any type of anesthesia poorly; it is consequently preferable to use local anesthesia in such cases. It is not recommended that wounds be sutured when operative intervention is performed during this period.

Fractures

When radiation sickness is conjoined with bone fractures the courses of the two processes complicate one another. In the presence of fractures radiation sickness takes a more severe course, this in

turn disrupting fracture-healing processes.

According to experimental data obtained on animals by A.G. Zem-
lyan, fractures heal more slowly against a background of radiation
sickness. The observed delay in bone regeneration varies on the aver-
age from 10 to 25 days. This slowing down of osteogenesis is most
marked during the height of radiation sickness.

In studying this process, V.I. Stetsula noted the following char-
acteristics of bone-tissue regeneration: a) a delay in the prolifera-
tion of the cellular elements of osteogenic tissue during regeneration
and in their differentiation; b) acceleration of the differentiation
of osteogenic tissue into bone on the 7th day; c) reorganization of
the newly formed bone tissue begins earlier and takes an accelerated
course; d) formation of a volumetrically small callus. This disruption
of bone regeneration is caused by the development of radiation sick-
ness and by local depression of restorative processes in the bones.

These characteristics of the course of bone fractures during
radiation sickness are of both theoretical interest and practical im-
portance. Careful immobilization of the injured portion of the body
not only improves the later course of the fracture, but also prevents
shock. A sparing method is used to restore the correct arrangement of
the bone fragments, all rules of anesthesia being observed. Consider-
ing the reduced reactivity of the organism, penicillin or other anti-
biotics are prescribed for prophylactic purposes even in the presence
of simple fractures. In cases of compound fractures antibiotics are
also introduced into the wound after it is carefully surgically treated.
It is necessary to keep in mind the rather frequent development of os-
teomyelitis and suppurative-septic complications taking the form of
phlegmon, erysipelas, anaerobic infections, etc. Considering these
characteristics of their course, the closing of a wound after surgical

treatment must be handled very carefully. Radical treatment of the soft tissues is carried out even when it is impossible to close the wound. Widespread resection of the bone fragments is not permissible, since this frequently leads to the formation of a false articulation.

Intraossal fixation of fragments is used only as an extreme measure in 2nd- and 3rd-degree radiation sickness. As a result of the frequent development of an infectious-necrotic process around the spine traction is employed only in the mild form of radiation sickness. Principally plaster casts are used in treating fractures.

Even in 1st-degree radiation sickness the period of immobilization must be increased by one-fourth of the ordinary time. This period must be even further extended in 2nd- and 3rd-degree radiation sickness.

Prolonged-Pressure Syndrome

When the shock wave causes buildings to collapse and heavy objects to drop and under other conditions individuals may be trapped beneath and crushed by debris for a considerable period of time. It is possible that the external tissues may not be damaged in this case. However, such closed soft-tissue wounds resulting from compression cause a severe condition called the compression syndrome. The severity of this condition depends on the time for which the pressure acted and the extent of the injuries, as well as on the localization of the trauma. The more widespread the trauma and the more prolonged the compression, the more serious is the prognosis.

The clinical picture of this syndrome may be divided into three periods: early, intermediate, and late.

During the early period, which lasts 1-2 days, the symptoms of the illness are not very marked and the victim's condition remains satisfactory so long as the pressure was low and of short duration.

Under powerful compression, the limb turns blue after 6-8 hours, a severe massive edema develops, and blisters filled with a serous or hemorrhagic fluid appear on the skin. The victim exhibits very marked symptoms of intoxication: adynamia, depression, and apathy develop. Hypotonia accompanied by a rapid weak pulse sets in. Symptoms of hemoconcentration appear: the amount of hemoglobin and the number of erythrocytes in the blood increase. The amount of urine excreted is sharply reduced and it contains proteins, free and lixiviated erythrocytes, and other formed elements.

The intermediate period begins on the third day. In severe cases symptoms of acute hepatic insufficiency develop and the patients die on the 8th-10th day, exhibiting signs of azotemic uremia. Blood pressure is normal or somewhat elevated during this period. Body temperature increases to $37.5-38.0^{\circ}$.

The edema and pain in the injured limb gradually abate. In milder injuries the signs of hepatic damage decrease after 10-12 days and the third period of the illness begins.

During the late period the pain in the injured limb recurs, sections of necrotic skin and muscle appear, and suppurative-septic complications easily develop against the background of the latter. Neutrophilic leucocytosis and anemia appear.

Treatment during the early period reduces to immobilization of the limb, analgization, and administration of cardiac stimulants and antishock drugs. Transfusions of plasma, banked blood, therapeutic serum, or blood-substitutes are given.

The patient receives a rich diet and a large quantity of sodium bicarbonate (2 g every three to four hours).

A lumbar novocaine block is set up when the quantity of urine excreted is considerably reduced. When symptoms of increasing azotemic

uremia are present during the intermediate period all measures normally used to cope with this condition are employed.

In order to reduce the toxic phenomena wide incisions are made in the injured limb and the fascial sheaths are opened.

Ordinary treatment of the wounds and necrotic sections is prescribed during the late period, antibiotics being widely employed.

When the compression syndrome is combined with radiation sickness administration of penicillin is prescribed from the first day after injury onward.

Burns

Treatment of burns against a background of radiation sickness is a serious problem, since such injuries may be massive in character and constitute the most numerous group. Burns are classified as light, thermal, radiation, and chemical. When injuries caused by ionizing radiation and burns are simultaneously present conditions are created for the mutual aggravation of these two processes. The severity of a burn is defined by two factors: its degree and the area affected. The affected body area is expressed as a percentage in accordance with B. Postnikov's system or Uolles' "rule of nine": burns on the head and neck — 9%, on the upper limbs — 9%, on the lower limbs — 18%, on the anterior surface of the trunk — 18%, and on the posterior surface of the trunk — 18%. The clinical picture of such burns has certain characteristic peculiarities: widespread hemorrhaging is observed at the site of injury, regenerative processes are severely depressed, granulations are decolorized, absent for some time, and easily injurable when they appear again, and putrefaction of the damaged tissues is occasionally observed. Sloughing of the scab and cicatrization of the burns are delayed and the scars formed ulcerate easily.

Ye.V. Stakhovskiy and O.S. Mesharev have established that the

microflora of combined burns are not particularly unusual, consisting of staphylococci, streptococci, protei, etc. They noted that microbes could be cultured more frequently from the blood and various organs when burns were conjoined with radiation injuries. The existence of toxemia in an organism weakened by radiation sickness leads to the development of infection. Widespread suppuration, abscesses, phlegmon, erysipelas, and sepsis frequently develop; anaerobic infections occur occasionally. The development of infection is also furthered by the fact that granulation tissue, which is known to be a barrier, is absent from the region of the wound surface for a considerable time as a result of the reduced regenerative capacity of the cells and tissues (B.M. Khromov).

The victim exhibits severe intoxication as a result of decomposition of the tissue of the burn surface and absorption of the toxic products thus formed. Burn shock frequently develops.

N.N. Priorov suggests that the following phases be distinguished in the clinical picture of thermal burns (these occasionally overlap and are combined with one another): shock, toxemia, infection, and reparative phenomena. He emphasizes the severe changes which occur in the body, these including hemoconcentration, an increase in the residual nitrogen content of the blood, a decrease in chloride content, development of acidosis, changes in metabolic processes, and disturbances of the activity of the liver, kidneys, and other organs. The treatment of combined burns and radiation sickness must be complex as a result of the multiple disturbances which occur. Against the background of radiation sickness shock, plasma loss, hemoconcentration, and intoxication must be prevented and local treatment of the burn simultaneously carried out.

First aid for burns in the focus of injury consists in extinguish-

ing smoldering clothing, exposing the burn surface (it is impossible to tear off or soak off clothing which adheres to the burn; it must be cut around the edges of the burn), and applying an aseptic dressing.

N.N. Priorov recommends that pain-relief measures be taken, standard ointment dressings applied, and sera and antibiotics be administered at the OPM (or a city hospital which has been spared). Morphine, caffeine, glucose solutions, and novocaine blocks are used to prevent shock. The most effective means of bringing a victim out of shock is to transfuse blood and blood-substitutes. The blood is injected into an artery in 3rd- and 4th-degree shock.

V.A. Polyakov, I.I. Revzin, and V.A. Marskiy have suggested a film of rapid-setting liquid plastic for the initial covering of burns. This film can be packaged and used for first aid and self-help. The liquid plastic is applied to the burn surface and, after several minutes, becomes a dense, transparent, elastic, airtight film. A solution of fast-setting No. 6 plastic containing analgesics and antibiotics has now been developed.

This fast-setting liquid plastic makes it possible to give first aid to a large number of simultaneously admitted burn cases.

During the second stage of medical evacuation by the GO, all required aid is rendered in a special hospital for burns. The primary surgical treatment of burns in casualties of ionizing radiation is carried out by ordinary methods, with preliminary analgization and administration of antibiotics. Nitrous oxide is recommended as an analgesic in addition to morphine and novocaine.

Patients bear up poorly under extensive necrotomy, shock frequently ensuing as a complication. In addition, the tissue bleeding is of itself an obstacle to operative intervention.

N.N. Priorov recommends:

1. Measurement of the area of the burn surface by Postnikov's or Vil'yamin's method or by the "method of nines" before treatment is begun.

2. Cleansing of the skin around the burn with a 0.25% solution of ammonia water, alcohol, or ether. The burn surface is treated with physiological solution from an irrigator.

3. Removal of large and medium-size blisters.

4. Application of pads moistened with penicillin (1000 units of penicillin in 100 ml of a 0.25% novocaine solution) to the burn surface. Four-layer gauze pads impregnated with vaseline oil or vaseline are placed above these. After applying a thin layer of cotton the burn surface is uniformly bandaged (the fingers are bandaged separately). The dressing is removed on the 8th-10th day when there are no complications.

5. Application of dressings which promote more rapid disengagement of necrotic tissue to 3rd-degree burns of wide extent: these dressings are wetted with hypertonic salt solution, a 5% solution of magnesium sulfate, or ronidase, which promote rapid enzymatic cleansing. A skin graft from the patient's own body should be performed soon (2-3 weeks) after the necrotic tissue disengages. When it is impossible to use the patient's skin, homotransplants and heterotransplants, i.e., cold-preserved transplants, are employed.

6. Cleansing of the affected area with hydrogen peroxide or physiological solution when the face is burned; blisters are opened at the base. The burn surface is smeared with a penicillin emulsion and left exposed.

7. Washing chemical burns under running water for 5-10 minutes. The affected area is then treated with a weak solution of an antagonistic substance: alkali burns with 1% acetic or citric acid, acid burns

with a 2-3% soda solution, and phosphorus burns with a 5-10% magnesium sulfate solution.

Because of the inevitable infection of burns a combination of antibiotics is administered parenterally as well as locally from the first few days after injury onward. Colimycin is used when protei or Bacillus aureus and Bacillus pyocyaneus are detected in the wound. Physiological solution (up to 4-5 liters per day for 2-4 days) is administered by the drip method to prevent dehydration and intoxication. P.D. Gorizontov recommends Belen'kiy's therapeutic serum as a tolerable inexpensive blood substitute. Blood substitutes, plasma, sera, or whole blood are administered as indications warrant.

Liberal drinking of a mixture of one teaspoon of table salt and 1/2 teaspoon of soda in a liter of water or mineral water is prescribed to prevent hypochloremia and acidosis. A 10% of sodium chloride is administered intravenously in a dose of up to 50 ml per day. Simultaneous intravenous injection of 50 ml of a 40% glucose solution and subcutaneous injection of 10 units of insulin are prescribed.

When symptoms warrant antishock drugs are administered and other antishock measures taken.

N.N. Priorov recommends the liquid preparation "ronidase" for preventing loss of plasma, cleaning the wound surface, and obtaining better granulation. When this preparation is used the wound surface is rapidly freed of ulcerations and epithelized. N.N. Priorov assigns special importance to the fact that scars become softer and more elastic and contractures of the joints are considerably reduced under the influence of "ronidase."

The aforementioned author recommends that burn cases also be parenterally given B.I. Zbarskiy and A.G. Bergauz's preparation called "Parentpit," which contains amino acids, the components of human tis-

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sue proteins. This drug is administered orally in a dose of 5-10 g per day for 10-30 days.

When burns are conjoined with wounds contaminated by radioactive substances surgical treatment should be conducted as soon as possible.

N.N. Priorov considers the most rational method of treating 3rd-degree thermal burns to be exsection of the damaged tissue and immediate plastic repair of the defect formed with banked homotransplants and heterotransplants. He emphasizes the necessity of performing various dermoplastic operations as early as possible; these promote very rapid healing of burns and prevent complications. During the recovery period specialized divisions of the burn hospital and other therapeutic institutions will be used for carrying out physical therapy and orthopedic treatment, therapeutic exercises being used to eliminate contractures, faulty limb position, and other residual phenomena.

Closed Cerebral Traumas

If closed cerebral traumas are conjoined with radiation sickness, the two processes complicate one another and make the prognosis worse. Such combined injuries to the nervous system have a definite peculiar clinical course.

During the initial period of the illness symptoms of cerebral trauma come to the fore; these include disruption of cerebral blood circulation, loss of consciousness and reflexes, meningeal symptoms, and occasional meningeal hemorrhaging.

All of these phenomena can completely mask or color the manifestations of radiation sickness, i.e., the initial reaction of the nervous system to the action of ionizing radiation.

As a result of the cerebral trauma the manifestations of radiation sickness which appear during the height of clinical symptoms are far more marked; the period of adynamia is more prolonged, the depression

of the central nervous system is more marked, and the trophic disturbances acquire a stable character. When closed cerebral traumas are present all processes acquire a retarded, sluggish character and recovery is prolonged.

A.D. Zurabashvili, A.A. Kvaliashvili, Ye.M. Semenskaya, et al. noted that radiation sickness takes a more chronic course when closed cerebral traumas are conjoined with experimental radiation injuries in dogs. The manifestations of radiation sickness were moderated, the dogs survived for several months, the depression of leucopoiesis was less marked, and the pathomorphological changes were more chronic in nature.

Treatment. If meningeal symptoms occur during the first period of combined injuries to the nervous system a diagnostic puncture is indicated in order that the cerebrospinal fluid may be analyzed and the cerebrospinal pressure determined.

Combined injuries to the nervous system basically require bed rest and protective therapy. In V.A. Baron's opinion, morphine and alcohol are contraindicated, particularly when there are injuries to the trunk. The same author recommends liberal drinking of preparations which intensify diuresis and administration of vitamins C, P, K, and B_{12} in order to detoxicate the organism. The first three vitamins are to eliminate the increased permeability and fragility of the blood vessels, while the last is to stimulate hematogenesis. Administration of antibiotics (penicillin, streptomycin, and biomycin) is indicated when combined neural injuries are complicated by infection.

Shock

The clinical picture of shock is characterized by the following diagnostic symptoms: the patient is pale, adynamic, and his face is occasionally cyanotic. The arterial and venous pressure is sharply re-

duced, the tongue is dry and coated, the face and extremities are covered with a sticky cold sweat, the pulse is weak, rapid, and thready, respiration is depressed and shallow, the heart sounds are thudding, the abdomen is soft, and the liver is enlarged. The patient is depressed and responds to questions with difficulty.

Shock requires immediate medical aid, without which the patient dies.

It is necessary to take into account the special sensitivity of such patients to cold, the first necessity thus being to keep them warm (with hot-water bottles, hot drinks, and coffee with brandy).

In the presence of combined radiation injuries traumatic shock is treated in accordance with the general principles of complex therapy. Special measures are:

1. Elimination of the flow of painful stimuli from the site of the trauma (immobilization of the limb, novocaine blocks, narcotics, sparing transportation, etc.).

2. Eliminating oxygen starvation and increasing blood pressure by means of transfusions of blood and antishock blood-substitutes.

3. Administration of antihistamines (dimedrol, phenamine, etc.).

It is now the patient's blood pressure and respiration rate rather than the erythrocyte and hemoglobin counts which are considered to be criteria of the severity of his condition. A drop in blood pressure to below 80 mm Hg is an absolute indication for blood transfusion, infusion of physiological solution having no effect in such cases (Braytsev). Considering that shock is accompanied by a decrease in the quantity of circulating blood, administration of caffeine and camphor when the blood stream is being destroyed is not very wise.

The blood pressure must be elevated as soon as possible by blood transfusions or administration of isotopic solutions, a careful con-

version then being made to the use of cardiovascular stimulants.

V.T. Mitrofanov used an antishock polyvitamin for treating radiation shock. The patient was given a solution of vitamins B_1, B_2, B_6, B_{12}, and PP, and folic, pantothenic, paraaminobenzoic, and ascorbic acids in physiological solution or 5% glucose intravenously. He obtained a stable increase in blood pressure, an improvement in the oxidative capacity of tissue, and an enrichment of the body in vitamins.

E.A. Asratyan, using Pavlov's teachings on the curative role of protective inhibition as his basis, proposed sleep therapy for shock. Pirogov also mentions the necessity and wisdom of prolonged sleep for shock patients.

Surgical intervention in shock patients is performed only in accordance with vital indications, when the operation itself is an antishock measure.

As for evacuation, victims with 1st-degree shock can withstand it. Patients with 2nd-, 3rd-, and 4th-degree shock are untransportable and are hospitalized in the antishock ward of the OPM, where all necessary antishock measures are taken.

Chapter 5

INJURIES CAUSED BY RADIOACTIVE SUBSTANCES AND
PRINCIPLES OF THE ORGANIZATION OF DOSIMETRIC MONITORING

Dermal injuries The action of the luminous radiation produced by
an atomic explosion causes ordinary thermal burns of different degrees,
it being necessary to differentiate these from dermal injuries caused
by the action of ionizing radiations. Acute and chronic dermal inju-
ries develop on exposure to ionizing radiations. Acute affections de-
velop during massive irradiations accompanying an atomic explosion or
after a short interval when the victim is exposed to medium and large
doses. Chronic dermal affections arise as a result of prolonged irra-
diation in small doses.

Two ways in which ionizing radiations may act on the skin may be
differentiated in injuries caused by atomic weapons:

a) dermal affection resulting from the action of penetrating ra-
diation at the instant of the atomic blast (γ-rays, neutrons);

b) dermal affection resulting from the action of radioactive fall-
out which directly contaminates exposed sections of skin and clothing
(β-particles).

A dermal affection of a certain degree develops in accordance
with the dose of radiant energy absorbed by the tissues. Four degrees
of dermal affection may be distinguished (see Table 9).

Thus, in those cases where severe dermal affections develop on
whole-body exposure to penetrating radiation they always occur against
a background of severe general symptoms of acute radiation sickness.

TABLE 9

Rough Data on Degree of Dermal Injury as
a Function of Absorbed Dose Received
during Exposure to Penetrating Radiation
(γ-Rays)

A Поглощенная доза в рентгенах	B Степень поражения	C Название поражения	D Ранняя реакция	E Скрытый период
400—500	I	F Субэритематоз-ный дерматит	G Отсутствует	H Около 3 недель (местно будет наблюдаться шелушение кожи, легкая пигментация)
500—800	II	I Эритематоз-ный дерматит	J Кратковремен-ная эритема	K До 2 недель
800—1200	III	L Буллезный дерматит	M Через 3—4 часа возника-ет выражен-ная эритема и отек	N 6—10 дней
O Свыше 1200	14	P Язвенный дер-матит	Q Вслед за об-лучением воз-никает си-нюшная эри-тема и выра-женный отек	R Отсутствует; или 3—5 дней

A) Absorbed dose, in roentgens; B) degree
of injury; C) type of injury; D) early
reaction; E) latent period; F) suberyth-
ematous dermatitis; G) none; H) approx-
imately 3 weeks (peeling and slight pig-
mentation of the skin are observed lo-
cally); I) erythematous dermatitis; J)
brief erythema; K) up to 2 weeks; L)
bullous dermatitis; M) marked erythema
and edema develop after 3-4 hours; N)
6-10 days; O) more than; P) ulcerative
dermatitis; Q) cyanotic erythema and
marked edema develop after irradiation;
R) none or 3-5 days.

Erythematous dermatitis is observed approximately 2 weeks after
whole-body irradiation in a large dose as a result of an atomic blast.
The bullous and necrotic processes which occur at still larger doses
virtually do not have time to develop, since the patient dies as a re-
sult of the whole-body irradiation before local processes can arise in
the dermal tegmina.

Table 9 is important in peacetime practice (x-ray therapy of lim-

ited portions of the body). In atomic explosions the entire body is usually irradiated with penetrating radiation and general symptoms of acute radiation sickness rather than local processes in the skin come to the fore.

Conversely, the second way in which the skin may be injured by ionizing radiation, i.e., by radioactive fallout (contact exposure to β-radiation), is of great importance when atomic weapons are used.

When the skin is subjected to β-irradiation by radioactive substances the local affections of the skin may proceed without symptoms of general radiation injury or with only slight symptoms of such a process.

The local reaction of the skin to exposure to ionizing radiation greatly resembles its reaction to sunburn. The only differences are a longer latent period, damage to deeper layers of the skin, and a more prolonged and persistent course for the former.

The following periods may be distinguished in the course of acute dermal affections caused by β-radiation:

1. The early reaction of the skin to irradiation.
2. The latent period.
3. The period of acute inflammation of the skin.
4. The recovery period.
5. The period of late sequelae and complications.

The earlier and more marked the first period of the illness and the shorter the latent period, the more severe will be the later course of the affection.

Dermal affections are characterized by the following general peculiarities: extremely slow healing, and formation of atrophic scars and trophic ulcerations with a tendency to malignant degeneration. All other conditions being identical, the areas of the skin covering bony

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prominences of the skeleton (the wrists, superciliary arches, anterior surface of the shank, etc.) and those in which large surfaces of skin are in contact (the axillary and inguinal folds, the genitals) are most affected.

The first period (early reaction) appears several hours, or more rarely several days, after irradiation and takes the form of erythema of varying degree. Petechia in the skin indicate a serious injury. After several hours the erythema may become cyanotic and a slight edema of the skin may develop. The erythema may last 2-3 days. All of the symptoms then disappear and the second period begins.

The second (latent) period lasts for from several days to three weeks. There are virtually no clinical symptoms during this period. The victims have no complaints and exhibit no changes at the site of injury. The latent period is of great prognostic importance: the shorter it is, the more severe will the further course of the process be. When the duration of the latent period is from several hours to 3-5 days tissue necrosis will develop later; a bullous affection will occur when this period lasts for from 6 to 10 days, while only a mild erythematous affection will occur if it is more than 12-15 days long.

The third period (that of acute inflammation of the skin) begins with the reappearance of erythema. When radiation burns are present this erythema has a reddish-brown or, quite frequently, bluish color. The skin·is edemic and has a glossy appearance. When a finger is pressed against it a long-lasting depression is left, this indicating tissue edema. As a result of the edema and cellular infiltration the injured section is somewhat thickened and is raised above the surrounding tissue. Decolorized areas indicate developing dermal necrosis. The appearance of petechial hemorrhages in the skin is a symptom of a poor prognosis.

Several days after the erythema recurs the epidermis is peeled away from the derma by the edemic fluid and blisters appear, the derma forming their bottoms. These blisters may cover the entire area of affected skin.

Large changes are observed in the tissues; these include destruction of the cells of the skin and its inclusions, shedding of the nails, dilatation of the capillary network, disturbances of the permeability of its walls, and hyalinosis of the vessels. Nerve endings are destroyed and trophic changes which propagate to deeper-lying tissue develop. Ulcers are formed in severe cases. The entire process is extremely painful; it is accompanied by severe pains, a burning sensation and numbness. When broad areas of the skin are affected the patient's body temperature increases and he exhibits symptoms of general intoxication. He becomes listless and drowsy, his appetite decreases, and a headache appears.

Depending on the severity of the inflammatory-necrotic changes the period of acute inflammation of the skin may last for from 2 to 8 months.

The fourth (recovery) period. The recovery period for different degrees of dermal affection varies. Thus, hyperpigmentation with subsequent peeling is observed for 1.5-2 months in erythematious dermatitis. The course of bullous dermatitis involving superficial blisters also usually proceeds favorably, the blisters gradually being resorbed, the erythema and edema abating, and epithelization proceeding rapidly under the membrane which bounds the blister. The entire process takes approximately one month. It is followed by peeling and pigmentation in individual sections. When the affections are more severe and erosions and ulcers develop, the process takes a longer course, atrophic scars accompanied by easily relapsing ulcers and fissures developing. The

regeneration process is extremely slow. In severe affections epithelization and cicatrization remain uncompleted, unhealing trophic ulcers being formed in the central areas. Tissue sclerosis is progressive. The epithelium and dermal cicatrices formed have a sharply atrophic character. Erosions and ulcers easily develop in the scar tissue.

The prolonged ulcerative process leaves the patient in constant danger of the development of sepsis, erysipelas, and amyloidosis for many months and years. When a dermal affection occurs against a background of acute radiation sickness the prognosis for the former becomes worse, since regenerative processes are depressed still further and sepsis easily develops.

The fifth period (that of sequelae). In erythematous dermatitis the dryness of the skin and loss of elasticity persist for a long time.

In bullous dermatitis the atrophic processes continue for a prolonged period, the hair on the affected areas falls out, and the sebaceous and sweat glands disappear.

Bullous or gangrenous dermatitis may be followed by the development of disfiguring atrophic and keloid scars with a tendency to malignant degeneration.

Dermal affections caused by β-radiations must be differentiated from chemical dermatites, sunburn, erysipelas, eczemas, blistering, and other diseases. Differential diagnosis is aided by: 1) knowing the radiological setup; 2) detecting contamination with radioactive substances; 3) a large number of identical injuries; 4) the appropriate symptomatology.

The prognosis for dermal injuries caused by β-radiation under conditions of mass injury depends primarily on the accompanying acute radiation sickness induced by external irradiation or incorporated radioactive substances.

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Severe injuries are usually in exposed areas of the skin, which are contaminated to the greatest extent by radioactive fallout. Clothing attenuates up to 40% or more of the β-radiation flux. Areas of the skin protected by clothing are usually affected to a lesser extent than exposed areas.

First-degree dermal affections, which encompass half of the body surface, may endanger the victims' lives.

Prophylaxis and first aid for contamination of the skin by radioactive dust incurred in mass injury consists in removing the dust from the dermal tegmina and clothing as rapidly as possible (see the section on partial sanitary treatment and decontamination), since the danger lies in contact exposure to β-radiation on direct contamination with radioactive dust. This prophylaxis and first aid must be given at the OPM.

Dermal affections with marked clinical symptoms are treated in the following manner at the suburban hospitals of the GO.

During the period of development of hyperemia and edema dermal affections are treated in virtually the same manner as thermal burns of corresponding severity. Use of citral dressings is recommended when pain and severe itching are present. Intraarterial administrations of 2-5 ml of a 1% novocaine solution or circular novocaine blocking with a 0.25% solution are recommended. These measures may halt or attenuate the course of the process in the skin.

When bullous or bullous-necrotic affections are present the skin must be carefully rubbed with alcohol and a sterile gauze pad applied. The contents of the blisters are then drawn out with the aid of a syringe. The membranes of the broken blisters must then be removed. The affected portions of the skin are washed with physiological solution or a weak solution of potassium permanganate. Ointment dressings

are then applied (citral dressings, penicillin ointment, synthomycin emulsion, aloe ointment, tezan emulsion, or gekserol).

Gekserol, a pepsin solution, or aloe ointment is used to clean the ulcerated areas.

Treatment of dermal affections caused by β-radiations proceeds slowly. The principles previously worked out for treating dermal affections caused by poisons of the yperite type must be observed in treating such affections, these including:

a) avoidance of nonsystematic use of various drugs, it being understood that the results of the treatment will not be immediately visible;

b) consideration of the three stages of a dermal affection (erythema and edema, i.e., the stage of exudation, the stage of slow disengagement of necrotic masses, and the regeneration stage), the appropriate drugs being used for each stage;

c) active prevention of secondary infection and suppression of such infection if it should occur;

d) systematic conduct of general restorative treatment, proper care and diet, and observance of a therapeutic-protective regime.

The patient should be assured complete bed rest and a full-value diet. All surgical interventions and changes of dressings should be carried out in complete accordance with the rules of asepsis and antisepsis. The patient's food should be high in calories, easily assimilable, and rich in proteins and vitamins; he should be given plenty of liquids.

It is necessary to exclude agents which irritate the skin (mechanical stimuli, traumas while changing dressings, use of irritating or caustic drugs, and exposure to sunlight, ultraviolet, infrared, or x-rays). When severe persistent pain is present promedol, omnopon,

fenadon, and morphine are prescribed in addition to internal novocaine blocking. Ointments containing anestezin are applied locally. It is recommended that affected limbs be splinted to ensure complete rest.

Repeated transfusions of blood in fractional doses, plasma, and sera are prescribed for general strengthening of the body and stimulation of regenerative processes. Blood is transfused in doses of 100 to 150 ml with intervals of 3-4 days between transfusions. A course of tissue therapy (vitreous body, aloe) or injections of Bogomol'ts' serum are recommended.

Dimedrol is administered internally in a dose of 0.05 g 2-3 times a day and calcium chloride is given intravenously in a dose of up to 10 ml of 10% solution as desensitizing agents. Large doses of vitamins C and B are indicated, as is vitamin K to reduce hemorrhagic symptoms.

When β-irradiation occurs jointly (external γ-irradiation in conjunction with contact β-irradiation) a dermal affection may develop against a background of radiation sickness; it is consequently necessary to carry out complex therapy of the radiation system in accordance with the scheme recommended in addition to local treatment of the skin.

Characteristics of the Course of Radiation Sickness when Radioactive Substances Enter the Body

The clinical picture of the radiation sickness which develops when radioactive substances penetrate the body differs somewhat from that of the radiation sickness which results from external irradiation: 1) the initial reaction usually has no symptoms; 2) the latent period is shorter; 3) the periods of the illness are less clearly distinguishable. Such symptoms of acute radiation sickness as severe emaciation, hemorrhaging in isolated sections of the skin, and shedding of hair during the height of the illness are frequently absent; 4) the illness

has a longer course and the recovery period sets in later. The presence of incorporated radioactive substances results in their having a continuous prolonged action on the body. As a rule, the systems through which the radioactive substances entered and the excretory organs are most affected; those portions of the body in which a given radioactive substance is selectively deposited are also injured. When radioactive substances enter through the respiratory organs the latent period is reduced to several hours, symptoms of general intoxication appearing even earlier (headache, drowsiness, sluggishness, and depression). External contact exposure to radioactive dust frequently results in the development of local catarrhal and catarrhal-suppurative conjunctivitis, laryngitis, pharyngitis, bronchitis, and inflammation of the lungs. Pneumonia usually has a hemorrhagic character and a severe course. Leucopenia develops later, during the height of the illness, and is not of the same extent as it is on whole-body irradiation with the penetrating radiation of an atomic blast.

When radioactive substances enter through the gastrointestinal tract the intestine is the most severely affected. Experiments on animals have shown that the large intestine is particularly afflicted, being one of the organs through which radioactive substances are excreted. Widespread inflammatory and necrotic changes may occur in the intestinal mucosa.

Leucocytosis appears during the first few days of illness, but is usually less marked than after external irradiation. Thrombopenia develops considerably later. Depending upon their point of entry, radioactive substances first cause an inflammatory reaction, this being followed by necrosis, tissue destruction and decomposition continuing after they have been excreted. A secondary infection (sepsis, erysipelas, or an anaerobic infection) easily develops when wounds and burned

areas are contaminated with radioactive dust. Tissue decomposition continues for weeks after the radioactive substances are eliminated. Healing proceeds extremely slowly.

The most characteristic difference between the late period of acute radiation sickness caused by external irradiation and that of affections produced by radioactive substances is the possible development of malignant tumors at points of preferential deposition of the radioactive substances.

First Aid for Contamination with Radioactive Substances

1. A gas mask must be put on the victim. When no gas mask is available the patient's face is covered with any material (preferably moistened) folded into several layers. Partial sanitary treatment and partial decontamination are carried out to remove radioactive substances from the visible dermal tegmina, clothing, and shoes.

2. Special care must be taken to protect the wounds and burned areas from contamination with radioactive substances by appropriate dressings.

3. The mucosa of the eyes, nose, mouth, and throat are carefully washed with pure water.

4. Measures are taken for rapid evacuation of the victim from the contaminated area.

The principles of treatment for incorporated radioactive substances are:

1. Elimination of the radioactive substances from the body as rapidly and completely as possible. Since radioactive substances in the body cannot be neutralized or suppressed, the only effective method of dealing with them is to remove them from the body by any available means.

2. Use of the general complex treatment developed for acute radia-

tion sickness.

When radioactive substances are ingested with contaminated water
and food vomiting must be induced mechanically or by emetics (a copper
sulfate solution or apomorphine). The patient is then given 25-30 g of
a suspension of various adsorbents (activated carbon, bone meal,
barium sulfate, and kaolin) and a copious gastric lavage is performed
after 10-15 minutes.

After a brief rest the administration of adsorbents and the gas-
tric lavage are repeated as indications warrant. Administration of a
large dose of saline laxatives before the lavage tube is withdrawn may
be recommended. Fatty laxatives should not be used, since they promote
the dissolving and absorption of certain radioactive substances. It is
wise to administer repeated high enemas 3-5 hours after radioactive
substances enter the gastrointestinal tract. For three days 200 ml of
5% magnesium sulfate is given every 5-6 hours and 1 g of the adsorbents
is administered 4-5 times a day.

All of these measures (vomiting, gastric lavage, and laxatives)
are effective if they are taken soon after the radioactive substances
enter the body. It is desirable that they be carried out within the
first half hour or the first hour and a half. These measures must con-
sequently be taken in the first aid station (OPM).

In order to accelerate the excretion of radioactive substances by
the kidneys the patient is given a large amount of fluids, liquids are
administered subcutaneously or intravenously, and theobromine, diure-
tin, and other diuretics are given at the same time. Merkuzal is con-
traindicated.

Enemas (preferably siphon) are recommended from the second half-
day after poisoning with radioactive substances onward.

When radioactive substances enter the lungs a portion of the radioactive dust is always swallowed; the measures taken must consequently be the same as those described above for entry of radioactive substances through the gastrointestinal tract. Expectorants (ipecac, thermopsis, and senega) and prophylactic inhalations of antibiotics in aerosol form are also prescribed. Nevertheless, a certain quantity of the radioactive substances is usually retained in the body and causes radiation sickness, the general principles of whose treatment are given above (see Chapter 3).

All of the aforementioned measures not previously taken may be employed during further treatment in the suburban hospitals. Drugs which form chemical complexes can be used to accelerate the excretion of radioactive substances from the body. These drugs form chemical compounds with the radioactive substances and promote their elimination. This results in a sharp intensification of the excretion of such substances. Prime among the complex-forming drugs are EDTA (ethylenediamine, tetracetic acid) and kompletsin. Both of these preparations are administered by intravenous injection in sterile 10% aqueous solutions. The injections are given twice daily for three to four days and then discontinued for three to four days. They are continued in the same manner after this latter period has elapsed. The entire course of treatment lasts one month.

The daily dose of kompletsin and EDTA is 40-50 ml of 10% aqueous solution. Each dose of these drugs is 20-25 ml of 10% aqueous solution. It is recommended that these drugs be administered intravenously by the drip method in an isotonic sodium chloride solution over a period of 3-4 hours.

Diseases of the liver, kidneys, and urinary pathways are contraindications to the use of EDTA and kompletsin.

In addition to the complex-forming drugs, administration of large amounts of liquids and of diuretics should be continued.

Diaphoretics and succagogues may be prescribed. Vitamin B_1, which acts as a complex-forming agent with radioactive substances as a result of the sulfur which it contains, should be administered. Injection of vitamin B_2 intensifies the oxidation-reduction processes in the body, also promoting more rapid excretion of radioactive substances.

When radioactive substances enter the body through the respiratory organs administration of complex-forming drugs by inhalation may also be recommended. This promotes removal of the radioactive substances with the sputum.

During treatment it is necessary to monitor the changes in the radioactivity of the blood, urine, and feces, as well as the sputum in certain cases.

Changes in the radioactivity of the blood and excreta are controls which indicate the effectiveness of the measures taken to eliminate radioactive substances from the body. Radioactive substances are excreted most intensively during the first-third-fifth days after poisoning, while they are still in the blood and soft tissues. Later, as osteotropic radioactive isotopes accumulate in the bones, their excretion is greatly hampered by the low activity of the metabolic processes which occur in bone tissue.

In clinical practice various combinations of thyroid and parathyroid hormones, ammonium chloride, viosterol (vitamin D_2), and calcium and magnesium gluconates are used to accelerate the elimination of radium and strontium deposited in the bones, as is periodic alternation of high- and low-calcium diets.

Summarizing the material given above, the following methods may be recommended:

1. Mechanical removal of radioactive substances (vomiting, gastric lavage, absorbents, enemas, expectorants).

2. Utilization of natural physiological mechanisms (diuretics, succagogues, diaphoretics, hormones, etc.).

3. Use of complex-forming agents (kompletsin, EDTA, sodium citrate, etc.).

A fourth method, internal administration of synthetic ion-exchange resins, also presents good prospects. The term synthetic ion-exchange resins refers to cross-bonded polymers containing acid or basic radicals and capable of exchanging their cations or anions for those contained in the solution (according to P. Kreych).

In the body these resins are capable of exchanging the labile ions of their large molecules for those of the radioactive substances, then being excreted in company with the latter. This method requires further experimental development.

Special features of care of patients. The patients' excreta (saliva, sputum, urine, and feces) are radioactive for the first 3-5 days and can be dangerous to those in the area. It is necessary to instruct medical personnel in the proper care of the patients. All excreta must be collected and buried at a depth of more than 1 m in specially designated areas far from any populated locality.

Patients severely contaminated with radioactive substances must be isolated for the first few days. Precautions must be taken in rendering aid to such patients, since otherwise the medical personnel will be contaminated and the entire area will become polluted with radioactive substances.

Characteristics of the Clinical Course of Wounds and Burns Contaminated with Radioactive Substances

The characteristics of the clinical course of wounds and burns

contaminated by radioactive substances result from a two-fold mechanism:

    1) the local action of ionizing radiation on the wound surface;

    2) the general action of radioactive substances which enter the body.

Wounds and burns contaminated with radioactive substances do not differ in outward appearance from ordinary wounds during the first few hours, and dosimetric monitoring of all wounds and burns in persons coming from areas of radioactive pollution must be carried out in order to detect contamination. The majority of the radioactive substances produced by an atomic blast are poorly soluble in body fluids and remain in the tissues of wounds and burns for a prolonged period, having only a local action. As B.M. Khromov has shown, the duration of this period depends on the following factors: the physicochemical properties of the radioactive substances, the quantity of these substances which enter the wound, the extent of operative intervention, and the individual characteristics of the victim. It is consequently important for practical purposes to know that, since the majority of the radioactive substances deposited in a wound (burned area) remain in the superficial tissues for a more or less prolonged period, they can be removed to a considerable extent by appropriate treatment. It is assumed that up to $3/4$ of the radioactive substances are fixed in the wound (burn) tissues and the remainder enters the blood and spreads through the body. The extent of the detrimental action of the ionizing radiations on the wound surface depends on the time for which the radioactive substances remain in the wound (burned area). Various degenerative, necrobiotic, and necrotic processes develop in the tissues of the wound surface. The ability of the cells in this area to multiply is depressed or completely suppressed. As B.M. Khromov has noted, the

peculiarities of a course of wounds contaminated by radioactive sub-
stances include frequent complication by suppurative, and occasionally
anaerobic, infections and slow epithelization accompanied by formation
of decolorized granulations which bleed easily. Healing consequently
proceeds considerably more slowly than in ordinary wounds. Considering
the extent of the detrimental action of radioactive substances on
wounds and the body as a whole, their role and importance cannot be
overestimated. When an aseptic dressing is applied to a wound, a con-
siderable portion (approximately half) of the radioactive substances
are absorbed with the exudate by the cotton-gauze pad; the other half
can be removed during surgical treatment. Up to 20% of the radioactive
substances may enter the body through the wound and become dangerous
during the first 2-3 hours.

The primary surgical treatment of wounds contaminated with radio-
active substances must be carried out as early as possible because of
the danger that such substances will be absorbed into the body and
their local action on the wound. The basic principle of this treatment
is maximum removal of the radioactive substances from the wounds. A
novocaine solution to which antibiotics have been added or ether anes-
thesia are usually used for analgesia; according to the experimental
investigations of B.D. Zabudskiy, the latter almost halves the resorp-
tion of radioactive substances. The skin around the wound must be care-
fully cleansed of radioactive substances before the wound itself is
treated.

B.M. Khromov recommends the following methods for the primary sur-
gical treatment of wounds contaminated with radioactive substances. It
must first be proven by dosimetric monitoring that the wound is con-
taminated.

The skin in the vicinity of the wound is first cleaned of radio-

active substances, being repeatedly washed with a soap solution (3-5%). The author feels that the use of ether and benzene is contraindicated in such cases, since these compounds promote more rapid absorption of the radioactive substances. The skin in the vicinity of the wound is then shaved, washed again, dried, and treated with iodine. Mechanical treatment of the wound itself is then begun, foreign bodies, blood clots, and areas of crushed and necrotic tissue being removed from its surface.

The wound is then copiously and repeatedly washed with sterile water or physiological or soap solution, as well as with a weak anti-septic solution, in order to remove the radioactive substances.

When radical removal of radioactive substances from the wound is required, its lips and bottom are exsected. In this case it is neces-sary to remove all foreign bodies which may serve as collectors of radioactive substances.

The wound surface is again washed and subjected to dosimetric monitoring. Further surgery depends on the extent to which the wound has been cleaned. If only a small quantity of radioactive substances remain in it, primary suturation is recommended when there are no sur-gical contraindications. If a considerable quantity of radioactive substances remains in the wound after surgical treatment, primary suturation is contraindicated. Suturation of such wounds creates a closed cavity and the radioactive substances are completely absorbed into the body with all the detrimental consequences which follow from this.

As is well known, retention of radioactive substances in the body can lead to acute or chronic radiation sickness. All this forces the surgeon to exercise care in his actions. In general, all surgical treatment of radioactive wounds must be carried out with punctilious

precision and precautions must be taken to protect the medical personnel from contamination with radioactive substances (working in an isolated operating room or on isolated tables in gloves, gowns, and masks and decontamination of instruments, medical materials, and dressings).

All that was said above about wounds contaminated with radioactive substances is equally true of thermal burns.

Wounds and burns contaminated with radioactive substances heal slowly. Considering this fact and the possibility that radiation sickness may develop in patients with such injuries, they must be evacuated to special suburban hospitals.

The problems of the surgical treatment of wounds and burns and the classification of casualties require further study and solution.

Protection against and Prophylaxis of Contamination by Radioactive Substances

Gas masks and equipment to protect the skin must be used in those portions of the focus of atomic injury which are contaminated by radioactive substances.

Gas masks protect against radioactive aerosols and dust, shielding the eyes and respiratory organs. When no gas masks are available it is necessary to cover the nose and mouth with a moist material (handkerchief) folded into many layers and to breathe through it. The principal task involved in protection in areas of radioactive contamination is not to permit radioactive substances to penetrate into the respiratory organs. Gas masks are consequently the main means of protecting persons in environments contaminated by radioactive substances.

Radioactive gaseous uranium (plutonium) debris — krypton and xenon — are not trapped by filter gas masks. As radioactive dust accumulates in filter gas masks they may become unfit for use. Such gas masks must be kept in storage; after the radioactive substances decay
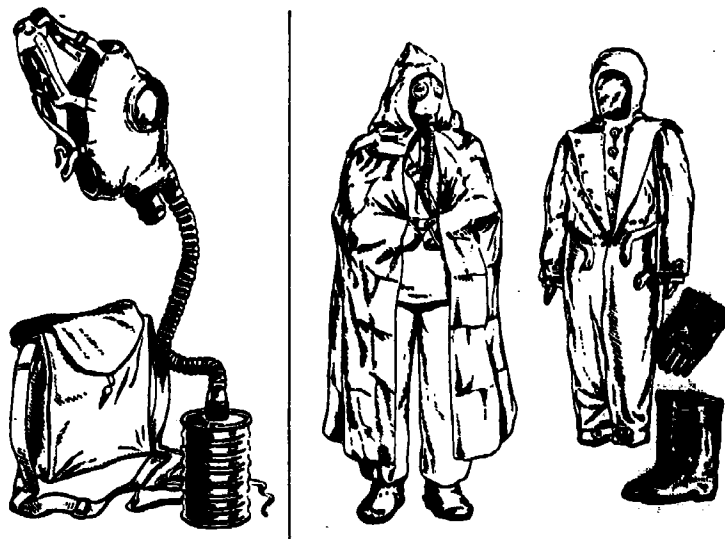
Fig. 12. Individual protective devices: a) gas
mask; b) protective cape which protects the cloth-
ing from liquid poisonous and radioactive sub-
stances; c) protective suit, gloves, boots, and
socks which protect the skin and clothing from
radioactive and poisonous substances.

they are again fit to be used.

Isolating gas masks (the KIP-5 etc.) must be used for protection
against inert radioactive gases.

Dust respirators are used for protection against aerosols under
laboratory conditions.

Protective capes, gloves, and socks and protective suits of vari-
ous types (Fig. 12) can be used for protecting the skin, clothing, and
shoes. When there are no special devices for protecting the skin,
various handy articles can be used (Fig. 13). Sheets, woolen blankets,
raincoats, etc. can be used instead of protective capes, sacking can
be wrapped around the feet over the shoes to take the place of protec-
tive socks, and ordinary leather boots, rubber galoshes, felt boots,
etc. can be used in place of special boots. Protective clothing and
gas masks reliably protect against α- and β-active substances, but not

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against γ-rays.

Devices for protecting the skin include protective capes, protective socks of rubberized fabric, and gloves. They are used in conjunction with gas masks for protecting the respiratory organs, skin, clothing, and shoes from contamination with poisonous substances and radioactive dust.

These devices are intended to protect the populace as they leave contaminated areas. In individual cases they can be used to protect the personnel of organizations of the GO.

In conjunction with a gas mask, a protective suit or coveralls with a rubberized cap, rubber boots, and protective gloves can be used for working in a contamined area. These outfits are intended for the mobile units of the GO, which must work in contaminated localities.

Protective aprons, socks (of rubberized fabric), and gloves (rubber) are used in conjunction with a gas mask or gauze mask for performing decontamination work on goods, transport equipment, and buildings. They are intended for work in decontamination areas (SOP, ODO, or OPM).

Protective filter clothing (PFC) can be used for protecting the skin of the personnel of units of the GO from exposure to radioactive dust and poisonous vapors. Protective filter clothing can either be impregnated with special substances or unimpregnated. A PFC outfit includes cotton coveralls of special cut impregnated with special substances, mens' underwear, a cotton cap, and two pairs of cotton socks, one of them impregnated with the same substances as the PFC.

The underwear, cap, and unimpregnated socks are used for insulating the skin from the protective filter clothing impregnated with special substances.

Gas masks, rubber gloves, and rubber boots are used in addition to the PFC set to protect the respiratory organs, hands, and feet from

Fig. 13. Handy protective devices: a) rubberized rain-
coat; b) vinyl chloride raincoat; c) leather jacket;
d) protection of feet with handy items.

exposure to radioactive dust or poisonous vapors.

The units of the medical service of the GO can be equipped with
both impregnated and unimpregnated protective filter clothing. The
coveralls of the PFC outfit can be impregnated by the personnel of the
units themselves. Aqueous solutions of special pastes are used for
this purpose (2 parts of paste to 1 part of water). Three liters of
solution are required to impregnate one PFC outfit.

The solution must be prepared before impregnation. Rubber gloves
can be worn to impregnate the PFC.

The dry impregnated protective clothing cannot be ironed with a
hot iron.

Care must be taken to preserve the integrity of the entire PFC
outfit when working in a focus of radioactive contamination.

If the integrity of the coveralls, boots, or gloves is disrupted,
the damage must be immediately repaired.

Partial decontamination of the protective clothing, boots, and

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gloves must be carried out after leaving the focus of radioactive contamination; this is done by careful wiping or shaking or by washing the radioactive dust off with water. The PFC must be taken off only at sanitary-processing stations.

Protective devices made of special-formula polymer materials are widely used under laboratory conditions for protecting the skin (they include suits, coveralls, aprons, and oversleeves). These devices have good protective properties, resist acids and alkalis, and are easily decontaminated.

For protection against γ-radiation it is necessary to leave the contaminated area rapidly or to take cover in a shelter.

Gas masks and protective devices cannot be removed at will in areas contaminated by radioactive substances; one cannot drink, eat, or smoke. Unless necessary one must not sit or lie on the ground or contaminated objects or go through dust-covered bushes and high grass.

The time for which one remains in a contaminated area must be kept to a minimum.

On contamination with radioactive substances it is necessary to conduct partial sanitary treatment and decontamination as soon as possible. In order to accomplish this the hands must either be carefully washed with soap in uncontaminated water or, when there is a shortage of water, the exposed portions of the skin must be wiped with damp pads (rags or handkerchiefs) in order to remove the radioactive dust from the surface of the skin. At the same time, it is necessary to shake or wash the radioactive dust from the clothing and shoes, i.e., partial decontamination must be carried out.

Later, on leaving the contaminated area, radiometric monitoring must be undergone. When contamination exceeding permissible levels is detected the individual in question must be subjected to complete san-

itary treatment in the clean-up area. During complete sanitary treatment the contaminated individual must wash carefully with hot water, soap, and a piece of bast. It is especially necessary to wash the hairy areas of the skin and hard-to-reach places (folds of skin, wrinkles, under the nails, and places where two areas of skin are in contact), where large quantities of radioactive dust may be retained.

For reliable removal of radioactive substances during partial and complete sanitary treatment it is necessary that the mouth be washed out and the nostrils, nasopharynx and auditory canal be rinsed with water. It is also recommended that the teeth be cleaned.

The quality of complete sanitary treatment is checked with a radiometer. Clothing, shoes, and other personal articles contaminated with radioactive substances belonging to casualties and patients must be decontaminated in specially equipped decontamination areas (the ODO of the OPM).

Various articles and objects are decontaminated by scouring, shaking, beating, rubbing, washing, laundering, etc. In decontamination it is necessary to achieve mechanical removal of radioactive substances from contaminated objects.

The organization and execution of complete sanitary treatment of those of the populace who have not incurred wounds, burns, or other injuries falls to a sanitary service set up to treat persons and decontaminate clothing. This service is based on community organizations and institutions.

One of the institutions of this service is the clean-up station (SOP). The medical service of the GO should maintain close contact with this service and furnish medical supervision of the quality of its work. In addition, the nurses who work at the SOP must furnish medical aid for mild injuries and wash out eyes and noses when necessary.

The SOP's are based on existing community institutions and their personnel must handle the organization and execution of decontamination measures for large segments of the populace.

During the warm season complete sanitary treatment may be carried out in uncontaminated open bodies of water, the direction of water flow being taken into account.

When SOP's are organized in temporary or adapted accommodations, the following requirements must be satisfied:

1. The SOP must be set up near the principal routes by which persons will leave the focus of atomic injury; access to it must be easy so that supplies may be brought in.

2. The grounds of the SOP and the area about it must have a sufficient water supply.

3. There must be shelters on the grounds of the SOP or in the immediate vicinity.

The sanitary treatment of injured persons must be carried out in the organizations of the medical service of the GO. Complete or partial sanitary treatment of injured persons can be conducted in the clean-up and decontamination (disinfection and degassing section of the ODO) of the OPM. It should be noted that the ODO can be used as an independent subdivision. High-capacity groups can be set up from several ODO's when necessary to ensure sanitary treatment to a large portion of the populace.

Public-health admissions personnel should be accommodated and used at stations for the sanitary treatment of persons contaminated by radioactive substances.

Principles of the Organization of Dosimetric Monitoring

The detection of radioactive substances in the air and on the ground is called radiation surveying. Radiation surveying has three

basic goals:

1. To determine the extent of radioactive contamination and the radiation level in a given locality.

2. To determine irradiation doses.

3. To determine the extent of radioactive contamination of various objects, persons, and animals which have been in a contaminated area.

Dosimetric monitoring is a constituent of radiation surveying. The second and third tasks of radiation surveying are essentially the goals of dosimetric monitoring.

Medical workers must always know the results of the radiation survey or, as it were, the radiation conditions.

Radiation surveying is conducted with the aid of dosimetric instruments. Four types of dosimetric instruments are used, each of them having its own designation: indicator, roentgenometer, radiometer, and dosimeter.

Indicators show the presence of radioactive contamination. This is the fundamental instrument in radiation surveying. It gives positive readings when radiation levels of hundredths and tenths of an r/hr are present.

Roentgenometers are a basic instrument of radiation surveying. They make it possible to measure accurately the radiation level (dose rate) in r/hr. The working range of roentgenometers is from 0 to 400 r/hr (Figs. 14a and 14b).

Beta-gamma-radiometers are designed to determine the contamination of various objects with beta-gamma-active substances. They express the degree of contamination in the following measurement units:

a) quantity of β-decays per cm^2 of the object's surface per minute; the working range is from 100 to 1,000,000 decays per cm^2 per min;
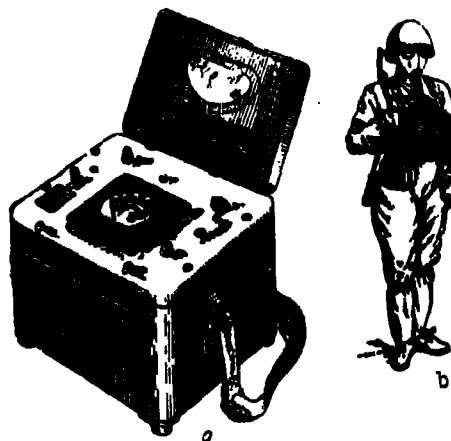
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Fig. 14. General view of radiometer (a) and its use for measuring the contamination of an object (b).
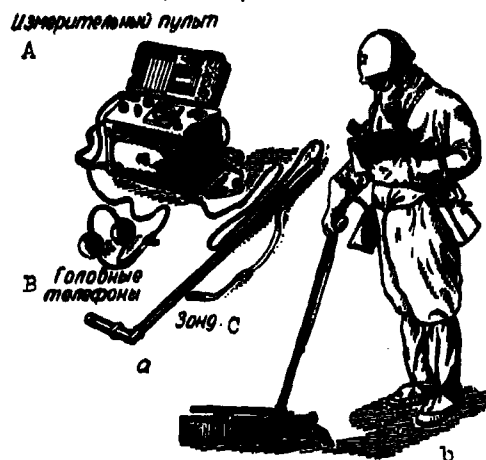

Fig. 15. General view of roentgen-ometer. A) Instrument panel; B) head phones; C) probe.

b) the radiation level in mr/hr, from 0 to 20 mr/hr.

The packaging (case) of every dosimetric instrument contains a logbook and instructions with a description of the instrument's layout and the rules for using it.

The boundaries of the area of radioactive contamination are determined from the indicator or roentgenometer readings in a given local-
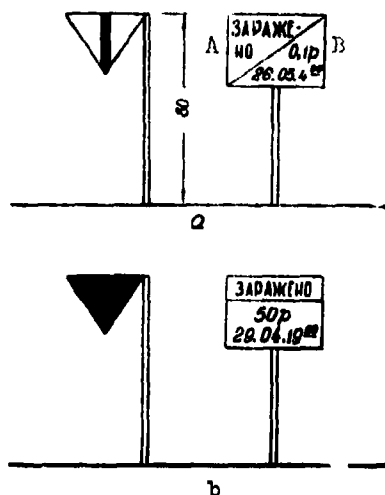
Fig. 16. Warning signs: a) for
a radiation level of 0.1 r/hr;
b) for a radiation level of 50
r/hr. A) Contaminated; B) r.

Fig. 17. The boundaries of contaminated
areas can be indicated in the above
fashion if no warning signs are avail-
able. A) Contaminated with radioactive
substances; B) r.

ity. The boundaries of the area of contamination are assumed to be at

a radiation level of 0.5 r/hr, those of the area of intensive contam-

ination at 5 r/hr, and those of the area of dangerous contamination at

50 r/hr. The boundary of a contaminated area can be indicated by a

yellow flag (caution) and that of an area of intensive contamination by a red flag (danger); the boundary of an area of dangerous contamination is designated by two rows of alternating red and yellow flags. It is recommended that the data obtained in radiation surveying be used as a basis for indicating the radiation levels in a locality with special markers, especially in those areas which persons may enter. These markers should contain the following information: a) the date of the measurement; b) the exact time of day when the dose rate was measured; c) the dose rate (radiation level).

The information on the marker may appear as shown in Figs. 16 and 17.

The total irradiation dose can always be determined from the data on the dose rate if the time for which the individual in question remained in the area of radioactive contamination is known. The permissible dose for man on systematic irradiation is 0.017 roentgens per day.

However, under extreme circumstances massive whole-body irradiations in doses of up to 50 roentgens are permissible, not presenting any danger to health and life.

Dosimeters measure the total irradiation dose in roentgens. Dosimeters may be individual or collective. Individual dosimeters are designed to indicate a maximum dose of 50 roentgens.

The total irradiation dose can be less precisely determined by the computational method. Graphs and tables are employed when this method is used. Table 10 is an example of such a table.

Let us solve two problems by way of example:

Problem No. 1: A victim of an atomic blast is in an area of radioactive contamination for two hours after the blast, the measured radiation level being 0.5 r/hr. The total irradiation dose received from

TABLE 10

Change in Dose Rate as a Function of
Time Elapsed after Blast (Standard Table)

A Время в минутах	Мощность дозы в B r/час	C Доза в рентгенах	D Время в часах	Мощность дозы в B r/час	C Доза в рентгенах
E мин.			F		
1 мин.	100	0,8	1 час	1,0	6,2
2 .	45	2,0	2 .	0,5	7,0
3 .	35	2,3	3 .	0,3	7,2
5 .	20	3,0	4 .	0,2	7,4
6 .	15	3,3	5 .	0,15	7,16
12 .	7	4,3	8 .	0,09	7,9
18 .	4,5	5,0	10 .	0,07	8,2
24 .	3,0	5,2	20 .	0,03	8,5
30 .	2,2	5,5	30 .	0 02	8,8
50 .	1,3	6,0	50 .	—	9,0
			100 .	—	9,3
			200 .	—	9,5

A) Time in minutes; B) dose rate in r/hr;
C) dose in roentgens; D) time in hours;
E) min; F) hr.

the radioactive substances contaminating the area is consequently 7¨
roentgens.

Problem No. 2: A victim of an atomic blast is in an area of radio-
active contamination for two hours after the blast, the measured radia-
tion level being 15 r/hr.

What is the irradiation dose in this area?

Solution: In the case in question the dose rate exceeded that
shown in the standard table by a factor of 30. The total irradiation
dose will thus be 30 times greater. We may set up the following pro-
portion:

$$0,5 : 7 = 15 : x$$
$$x = \frac{15 \cdot 7}{0,5} = 210 \text{ r.}$$

In order to solve problems Nos. 1 and 2 it is necessary to take
into account the fact that the actual irradiation of both victims is
considerably higher if they were in an unshielded area at the instant
of the blast and were subjected to the action of penetrating radiation,
since the total irradiation dose equals the dose received at the in-
stant of the blast from the action of its penetrating radiation plus

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the dose received after the blast as a result of radiation from the radioactive substances contaminating the area.

Knowing the irradiation dose, during the first or second period of acute radiation sickness we can roughly determine the degree of severity of the illness and decide on its prognosis.

The basic tasks of dosimetric monitoring in the organizations and institutions of the medical service of the GO are:

a) to determine the irradiation dose received by victims admitted for treatment and for personnel of units of the GO working in the atomic focus or at decontamination stations, clean-up stations, etc.;

b) to determine the extent of contamination with radioactive substances of clothing, shoes, public-health vehicles, various types of medical supplies, and persons coming from the atomic focus (their skin, the surfaces of their wounds and burns, their blood, and their excreta);

c) examination of food products and water for contamination with radioactive substances.

Dosimetric monitoring must be carried out in all mobile units and fixed institutions of the medical service of the GO.

Responsibility for the execution of dosimetric monitoring lies with the supervisory personnel of the units and institutions of the medical service of the GO.

The supervisors of the units and institutions of the medical service have given large tasks in the organization and execution of actual aid to the chief radiologists of the various staffs of the service, the radiologists of the USEB, and the radiological units of the specialized medical-aid group.

There are appropriate laboratories in the classification-evacuation hospitals and the main and specialized suburban hospitals for clinical examinations of blood and excreta.

Radiometric divisions of the laboratories of the medical service of the GO based on the public-health and epidemiological stations have been set up for sanitary-hygienic investigations of food products and water.

Finally, radiological stations have been set up in the medical service of the GO to train dosimetrists and personnel for technical inspection and repair of dosimetric apparatus. These are based on the existing x-ray stations, chairs of radiology and roentgenology, and other roentgenological and radiological institutions.

During the first stage of medical evacuation, at the first-aid stations, dosimetric monitoring has the following tasks:

a) classification of the victims into those contaminated by radioactive substances and those not contaminated;

b) determination of the rough irradiation doses received by the victims, proceeding from their anamneses and the radiation conditions;

c) determination of the completeness of the decontamination of clothing, shoes, and medical and household health supplies, the completeness with which radioactive substances have been removed from wounds and burned areas, and the quality of sanitary treatment;

d) monitoring of the irradiation doses received by the personnel of the OPM and the units attached to the station in question which work in areas of radioactive contamination.

In order to execute these tasks the OPM includes a laboratory staffed by six persons, these being a laboratory director, three combined laboratory workers and dosimetrists, and two combined nurses and dosimetrists. Dosimetric monitoring occupies two men in the RP of the OPM and one man in the decontamination area. The two nurses carry out dosimetric monitoring in the operating and dressing department (one) and in the sanitary treatment area of the ODO (one). The laboratory

chief must monitor the irradiation of the personnel of the units attached to the station. All of the dosimetrists are equipped with β-γ-radiometers. Radiological (radiometric) laboratories for examining biological media (blood, urine, feces, sputum) for radioactive substances are organized in the hospitals of the suburban zone, primarily the SEG and the main hospitals. It is wise to have a similar laboratory in the specialized hospital for radiation injuries. In addition to training dosimetrists and laboratory workers in special institutions or in groups, it is wise to acquaint all medical personnel with the principles of the dosimetry of ionizing radiations.

Timely detection and removal of radioactive substances is one important measure for preventing or reducing the injurious action of ionizing radiations on man or animals.

The work of the dosimetrists in the RP of the OPM includes determining the extent to which the victims admitted are contaminated (see the chapter on classification). Two dosimetrists must work in the ODO of the OPM, one in the area where clothing is decontaminated to determine the completeness of this decontamination and the other (a nurse) in the sanitary-treatment area to determine the effectiveness of this treatment.

The nurse-dosimetrist who works in the operating and dressing division monitors all wounds and burned areas before surgical treatment in order to detect radioactive substances, also performing this function after the surgical treatment in order to determine the completeness with which the wound or burned area has been decontaminated (the radioactive substances have been removed).

A second, no less important task of the medical nurse-dosimetrist in the operating and dressing section of the OPM is to detect radioactive substances on instruments, apparatus, other objects, and dressings

in order to determine the necessity for and completeness of decontamination. Partial decontamination of the supplies of the larger units (public-health forces, medical squads) is carried out by the personnel of these squads when they leave the contaminated region. Decontamination must be performed in gas masks. If measurement establishes that the medical supplies (stretchers, bags, kits, etc.) are still contaminated in excess of the permissible level after partial decontamination, the unit and its equipment are sent to the decontamination area of the clean-up and decontamination station or to the ODO of the OPM for complete decontamination. After the supplies are completely decontaminated the same is done for the individual protection devices and complete sanitary treatment then follows.

Decontamination of medical instruments must be carried out in the operating and dressing section of the OPM or in the operating units of hospitals which have been spared.

Instruments can be decontaminated by the following method.

The instruments are washed in a hot soda solution in order to remove blood clots (or pus), then in running water, and when no traces of blood turn up in two or three trays they are carefully scrubbed with brushes and gauze or cotton pads to remove mechanically the radioactive substances. When the instruments are contaminated with radioactive iron (Fe^{59}), cerium (Ce^{144}), cobalt (Co^{66}), strontium (Sr^{89}), etc., it is wise to fill the trays with dilute solutions of sulfuric or nitric acid (for rapid removal of the radioactive contaminants).

After being washed and mechanically cleaned the instruments are subjected to dosimetric monitoring; when there are no radioactive substances they are sterilized, while when such substances remain they are returned to be further washed, the solutions in the trays being changed. Instruments should be decontaminated only in gloves.

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When dressings are to be decontaminated the outer wrapper must be removed from the bandage, cotton, or gauze, measures being taken to prevent the radioactive substances on the wrapper from coming into contact with the bandage or cotton. The dressing wrappers, as well as water or solutions in which instruments or wounds and burns were washed, must be collected in a special vessel and buried at a depth of no less than 1 m.

Partial decontamination of public-health vehicles is carried out as they leave the contaminated region by automobile maintenance personnel. This culminates in mechanical removal of visible particles of dirt and dust with rags, those portions of the automobile with which the service personnel came into contact most frequently being gone over two or three times (levers, doors, etc.).

Complete decontamination of public-health vehicles is carried out at vehicle-decontamination stations (or areas). It is accomplished by washing the vehicle with pressurized streams of water or by mechanical removal of the contaminants (with rags or scrubbers); individual components or units must be washed in kerosene or benzene and radioactive dust can be removed (from the hood or cab, for example) with a vacuum cleaner.

We mentioned above that one of the tasks of the OPM is dosimetric monitoring of the irradiation doses received by the personnel of the units attached to the station. The OPM is equipped with a collective dosimeter (a DP-21 or DP-22) for this purpose. This outfit includes 200 individual dosimeters and a charge-measuring device.

The laboratory director of the OPM furnishes individual dosimeters to the units which are to work in areas of radioactive contamination.

It is not necessary to issue an individual dosimeter (Fig. 15) to each member of a unit to determine the rough irradiation dose. If the

personnel of a unit such as a sanitary brigade work in one area, it is sufficient to issue individual dosimeters to one or two of the members of this brigade. The dose received by each man in the brigade can be evaluated from the dose received by these persons. It is necessary to keep a file card on the dosimetric monitoring of each unit of the GO which works in an area of radioactive contamination.

The radiological stations have the task of checking the technical condition of all dosimetric apparatus and eliminating slight technical troubles in their operation (including checking the correctness of readings). The radiological stations must serve as the base for the initial and advanced training of dosimetrists.

The laboratories of the medical service of the GO are organized to examine food products and water to determine whether radioactive substances are present. Such laboratories may be based primarily on public-health and epidemiological laboratories and specialized institutes. All personnel of the laboratories and quality-control units of food plants must be trained in the selection of tests, transportation of food products, and detection of radioactive substances in such products and in water.

In the laboratories of the animal- and plant-protection service of the GO examinations are made of forage, agricultural products, and water for indications of radioactive substances and to determine the necessity for and completeness of decontamination. All of these measures are intended to keep animals or persons from ingesting radioactive substances with their food.

A clean-up and decontamination section (for disinfection and degassing) is set up in the OPM.

One of the principal tasks of this section is to decontaminate clothing and shoes and carry out sanitary treatment of casualties (the

remainder of the populace and, in certain cases, persons having mild injuries can receive sanitary treatment and have their clothing and shoes decontaminated at the clean-up stations of the service for sanitary treatment of persons and decontamination of clothing of the GO).

Decontamination of clothing and shoes and sanitary treatment of casualties at the ODO simultaneously solves the problem of protecting the personnel of the medical departments of the OPM from contamination with radioactive substances.

The admissions personnel of city hospitals which have been spared should be prepared to decontaminate clothing and shoes and carry out the sanitary treatment of casualties.

When necessary, floors (not rooms) should be set aside in these hospitals for the decontamination of clothing and shoes.

In the suburban region decontamination of clothing and shoes and sanitary treatment of casualties hospitalized there is carried out by the admitting and classifying departments of the SEG's or main hospitals. The remaining casualties are treated in specialized hospitals, where dosimetric monitoring is also set up.

It was noted above that radiological laboratories for determining the content of radioactive substances in biological media are set up in the classifying and evacuating hospitals and the main hospitals. Tests for analysis may be sent to these laboratories from other suburban hospitals.

When radioactive substances enter the body both the patient himself and his excreta are subjected to dosimetric monitoring. When the radioactive substances are uniformly distributed throughout the body the blood is also investigated during the first few days after contamination. In order to make correct calculations when only small quantities of radioactive substances are excreted it is necessary to take

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into account the background radiation. Background radiation is caused by the presence of natural radioactive elements and the action of cosmic rays. Thus, for example, the natural radioactivity of the soil is $2 \cdot 10^{-8}$ curies/kg, that of river and sea water is 10^{-11} to 10^{-12} curie per liter, and that of air 10^{-13} curie/liter. The natural radioactivity of a 24-hour urine specimen averages 1000-3000 decays per minute or 0.004-0.0013 µC.

Dosimetric monitoring is also carried out for the early diagnosis of and determination of therapeutic measures for wounds and burns contaminated with radioactive substances. A.T. Sautin recommends the following method for this purpose:

a) in order to remove the radioactive substances the skin around the wound or burned area is treated for a radius of 10-15 cm with cotton-gauze pads moistened with water or with a 2-3% solution of citric acid when the contamination is of considerable extent. In order to avoid additional introduction of radioactive substances into the wound the cleaning should be carried out from the wound toward the periphery, the liquid not being permitted to flow into the wound.

When the injured or burned area is large (more than 10 × 15 cm in area) the contamination of the surrounding skin is not reflected in the results of the dosimetry;

b) in order to determine the total radioactivity the head of a probe (sensor) is held at a distance of 1-1.5 cm from the surface of the wound or burn for 1 minute. The total radioactivity is expressed in decays per minute per cm^2 or, in accordance with the radiation from the wound, in mr/hr;

c) in order to determine the degree of contamination a piece of sterile filter paper 3 × 8 cm in size (several pieces when the wound is of large size) is held against the wound for one minute, the number

of decays per minute per cm^2 in these filter papers then being determined with a β-γ-radiometer;

d) when deep multiple wounds are present a sterile cotton-gauze pad is introduced into the cavity formed for one minute and then dosimetered.

The author emphasizes the wisdom of determining the contamination of wounds and burns during the first 5-8 hours, since the quantity of radioactive substances is gradually reduced by absorption. When wounds and burns are contaminated with radioactive substances the greatest tissue radioactivity is found around the injury, while induced radiation produces an identical tissue radioactivity throughout the entire body. In order to distinguish superficial contamination with radioactive substances from induced radiation A. I. Sautin recommends careful wiping of the area of the skin under investigation with a cotton-gauze pad which is then dosimetered. The pad will be uncontaminated if induced radiation is present.

Chapter 6
GENERAL PRINCIPLES OF THE CLASSIFICATION AND
EVACUATION OF RADIATION CASUALTIES

The term medical classification refers to the division of casualties and patients requiring the same therapeutic and evacuation measures into predetermined groups in accordance with medical indications and the amount of aid which can be rendered in the stage of medical evacuation in question and in subsequent stages.

The term "classification" and the basic principles of this procedure were first formulated by N.I. Pirogov. The problem of the medical classification of casualties and the sick in the theater of military operations was later worked on by V.A. Oppel, N.N. Burdenko, and a number of other Soviet scientists.

In its modern sense the classification of casualties and patients is the basic condition which ensures execution of a scientifically grounded system of step-by-step treatment with evacuation as warranted. When massive casualties occur as a result of the use of weapons of mass injury medical classification becomes of prime importance in the general complex of medical care. Rapidly and skillfully conducted classification is obligatory for the timely rendering of medical aid and rapid evacuation as warranted.

Clear and rapid medical classification requires a good medical training and the ability to become familiar rapidly with a large number of varied casualties. In some cases it is necessary to decide to which group a given casualty (patient) belongs from external signs of

injury and questioning.

The importance of medical classification is especially great when it is necessary to reduce the amount of medical aid rendered and postpone a number of therapeutic and prophylactic measures.

Considering what has been said above, all personnel of the organizations and institutions of the medical service of the GO must be instructed in the basic rules for medical classification in the various stages of evacuation. This does not mean that any definite standard (formula) must be developed, since medical classification is not a rigid procedure, its content being completely dependent on the specific general and medical arrangements which have been made, the amount of medical aid to be rendered in the various stages of medical evacuation, and other conditions.

Medical classification must be based principally on diagnosis and prognosis, and there is consequently no practical necessity for differentiating four types of medical classification — diagnostic, prognostic, intrastation, and evacuation-transportation. Two basic types of medical classification, intrastation and evacuation-transportation, must consequently be carried out at each medical station.

Intrastation classification determines the order in which patients go to the functional subdivisions of a given medical station, the character and severity of their injuries being taken into account.

Evacuation-transportation classification determines the hospital (beyond the station in question) to which the patient will go, during which stage (I or II), how he will get there (automobile, ship, airplane, railroad), and in what position (sitting, lying).

The medical service of the GO has adopted a two-stage system of medical evacuation.

The organizations and institutions which render first aid and in-

itial medical treatment are the first stage of medical evacuation.

Institutions where casualties receive specialized care and treatment are the second stage of evacuation.

During the first stage of evacuation, i.e., in the focus of injury itself, first aid is rendered to casualties by the personnel of the health brigades and other large units and by the nurses of the PSG.

The goals of the initial medical classification of victims are to render them urgently needed medical aid as soon as possible and evacuate them to the nearest treatment station rapidly and rationally. In the focus of mass injury these stations are most frequently first-aid stations (OPM) or hospitals which have been spared.

In a remote area of the field of operations the nurses of the PSG and the commanders of the public-health brigades organize the search for and removal of casualties after having become familiar with the situation, render first aid, and classify the victims. When these tasks are done the nurses of the PSG and commanders of the public-heal.. brigades must make sure that the medical personnel first treat casualties with arterial hemorrhaging, penetrating wounds of the abdomen, chest, and skull, widespread burns, and symptoms of severe acute radiation sickness.

After the casualties receive first aid they are brought to a temporary station for assembling the victims (VPSP), one or two of these being set up for each SD in accordance with the specific situation. (In some cases such stations need not be set up.)

At the VPSP the nurses of the PSG carefully check the correctness of the aid rendered, giving orders when necessary or themselves adjusting the tourniquets, splints, and dressings which have been applied; they also determine the order in which casualties will go to the medical station of the OPM and the positions which they will take in the

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vehicles which transport them, the latter depending on the severity
and character of their injuries.

This selective approach to and order in the rendering of first
aid is intended to make such aid timely and to permit the casualties
to be removed from the focus of injury as rapidly as possible.

The nurses of the PSG in the focus of mass injury thus supervise
the public-health brigades in their rendering of medical aid to the
victims and classify the casualties according to the severity of their
injuries so as to determine the time and sequence of their removal to
the OPM and other city hospitals.

Execution of these tasks is one of the decisive factors in saving
the lives of the severely injured and in improving the outcome of the
treatment of casualties.

The nurses of the PSG will not be able to locate and separate
casualties with wounds contaminated by radioactive substances. When
they find a person with symptoms of acute radiation sickness they must
send him to the OPM or the nearest city hospital on a stretcher.

No other measures are required for this group of persons.

Among the unconscious victims with traumas and burns may be some
with severe and moderately severe acute radiation sickness. Certain of
them may exhibit vomiting, dizziness, and other symptoms of this ill-
ness. After being given first aid for their traumas and burns this
group of persons must be sent to the OPM on stretchers. Intrastation
and evacuation-transportation classification must be carried out at
the OPM.

Intrastation classification at the OPM is basically executed by
the admitting and classifying section. This department is one of the
most important in the station. If the classification of casualties at
the OPM is organized and carried out skillfully the victims will re-

ceive the necessary aid at the proper time and better conditions will be created for the work of the other departments of the station and the hospitals in the second stage.

The basic principles of the medical classification of casualties with radiation injuries in the PSO of the OPM are: 1) presence or absence of radioactive contamination, this being determined with radiometers in the RP and 2) the severity of the injuries, this being determined by the clinical symptoms, the readings of individual dosimeters, or the data from the radiation survey, which has established the radiation level in each zone of the focus of injury.

All of the victims admitted to the RP of the OPM are divided into two groups:

a) when the level of radioactive contamination exceeds the permissible norms the casualties are sent to the ODO for sanitary treatment and decontamination;

b) casualties having a level of radioactive contamination below the permissible norms or not at all contaminated with radioactive substances are sent from the RP to the admitting and classifying section.

Patients in serious condition requiring immediate surgical aid are an exception to this rule. These will most frequently be victims with hemorrhages, shock, severe combined injuries, burns, and fractures of major bones and persons irradiated in doses of more than 600 roentgens.

Despite radioactive contamination exceeding the permissible level victims in this group must be sent from the RP to the admitting and classifying department or directly to the operating and dressing section, where they must be subjected to partial sanitary treatment and decontamination and given immediate medical (surgical) aid in accordance with the indications of contamination. Their clothing and shoes

are sent to the ODO.

From the admitting and classifying section of the OPM victims
with radiation injuries are sent directly to the evacuation department
for later evacuation to suburban hospitals when they exhibit symptoms
of acute radiation sickness, to the operating and dressing department
when vital indications show them to require operative intervention and
dressings, and to the antishock ward when they are in a state of shock.

Victims exhibiting marked early symptoms of acute radiation sick-
ness must be included among the seriously injured.

Clinical examination of radiation casualties is not possible at
the OPM. In order to solve the problems of evacuation-transportation
classification it is necessary to take into account the victim's gen-
eral condition, the presence and severity of symptoms of acute radia-
tion sickness, the time of their appearance, the irradiation time, and
the approximate irradiation dose received.

Casualties who received an approximate irradiation dose of 100 to
200 r and exhibit symptoms of the mild form of acute radiation sickness
do not require immediate medical aid and can be evacuated from the OPM
to the suburban hospitals in the second stage. This group of victims
can be evacuated in sitting position, by automobile or other means of
transportation.

In working in the OPM it must be understood that mild symptoms of
radiation sickness during the first and second periods can later lead
to severe affections with unfavorable outcomes.

When combined injuries which include radiation affections are
present, classification at the OPM is based on the victim's condition,
the prevalence of a given type of injury being taken into account.

When the estimated irradiation dose is 200 r or more and symptoms
of acute radiation sickness are marked the victim is sent from the OPM

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to a suburban hospital. As a rule, these are litter patients. Untransportable radiation casualties, including those with combined injuries, are kept at the OPM and can be evacuated to the nearest city hospital on stretchers.

It is important to note that victims with open wounds and burns must be subjected to careful dosimetric monitoring in the operating and dressing department in order to determine whether radioactive substances are present in the wounds or burned areas, a lookout also being kept for debris, which produces a considerable radiation level.

It is known that the presence of radioactive substances in a wound or on a burned area is a great danger to the victim's life; removal of the radioactive substances from the wound or burned area and extraction of radioactive debris are extremely necessary and must be conducted as soon as possible at the OPM.

A GO medical card must be filled out for each victim in the admitting and classifying section of the OPM (see Fig. 17).

In addition to the identification section, the card notes the character of the injury, its localization, the diagnosis, and the basic therapeutic and prophylactic measures taken.

The GO medical card is filled out at the OPM or one of the other units or hospitals of the first stage and must accompany the victim until he recovers or dies. The cards come with strips of four different colors: black indicates that the victim must be isolated, red that he requires immediate medical aid, yellow that he has been injured by chemical warfare agents, and blue that his wounds are contaminated with radioactive substances. If the victim requires immediate medical aid all the strips are torn off except the red one. When radioactive substances are detected on his clothing or shoes, in his wounds, or on his skin or burns only the blue strip is retained.

After the victim has received sanitary treatment, his clothing and shoes have been changed or decontaminated, and the radioactive substances have been removed from his wounds or burns the blue strip is torn off.

The cards are supplied in pads of 100.

The medical recorder simultaneously fills out the GO medical card and its stub (see illustration below). The card is torn off and sent with the victim, while the stub is kept in the admitting-classifying or evacuation department of the OPM or is retained by the city hospital and serves as the basic document on which medical reports are written. When treatment is complete the stub of the GO card must be sent to the administration of the classification and evacuation base which directs the work of the OPM in question.

The reverse side of the card is used for special notes by the doctors of the medical divisions of the OPM or the city hospitals. Here the physician can indicate facts to which the personnel of the medical brigade must pay special attention, the care which the patient should have en route, and other important information.

On the reverse side of the card is a place for recording the successive stages of medical evacuation. The medical personnel attending the victims can make notes here when necessary. Special notes may be written on the reverse side of the stub by the medical personnel of the admitting and classifying department of the OPM or of whichever hospital filled out the card.

Evacuation-transportation classification is carried out by the evacuation division of the station. In addition, problems of evacuation-transportation classification can be resolved in the operating-dressing and admitting-classifying departments of the station, i.e., in those sections where the victim receives medical aid or is diagnosed.

In conducting evacuation-transportation classification at the OPM
the victims must be divided into three groups: those with mild injuries,
those transportable casualties with moderately severe injuries, and un-
transportable patients with severe injuries. Persons in the first group
can be sent to hospitals for the slightly injured by vehicular trans-
port or on foot, while those in the second group are sent by vehicular
transport through the medical assignment post to the SEG or main hos-
pitals. Untransportable patients must be evacuated on stretchers to
the nearest city hospital which was spared. Depending on conditions,
hospitalization and treatment of untransportable casualties can be or-
ganized in spared buildings near the OPM. Untransportable casualties
cannot be permitted to accumulate in the OPM, since this can consider-
ably hinder its work.

In evacuating casualties from the OPM the character and severity
of their injuries must be taken into account. Persons exhibiting symp-
toms of radiation injury alone or in combination with other traumas
and burns must be moved in individual automobiles as far as possible.
This enables them to reach the specialized hospitals most rapidly and
facilitates the work of the MRP.

The above-described principles of the classification of victims
with radiation injuries are observed in the hospitals of the bombed
city.

However, the classification principles used in these hospitals
may differ from those employed in the OPM. Let us first point out that
spared city hospitals may handle different volumes of medical care.
This might apply to institutions which deal only in the surgical treat-
ment of wounds, immobilization, and dressing, while others may render
specialized medical aid, including gross operations and the hospital-
ization and treatment of certain types of casualties.

A Медицинское донесение

B о движении пострадавших
D

C по состоянию на . ° ч.° за . °____19 г.
E Кому _____

F Пораженных	G Состоял	H Поступило	I Эвакуировано	J Умерло		M Состоит				R
				K до операции	L после операции	N всего	O из них ожидает оказания помощи	P подлежит эвакуации	Q находится в стационаре	
S С лучевой болезнью										
T С ожогами										
U С различными травматическими поражениями										
V С комбинированными поражениями										
W С поражениями БОВ										
X С инфекционными заболеваниями										
Y Итого										
Z Начальник _____										

A) Medical record; B) movement of casualties in; C) situation at; D) o'clock on; E) to; F) casualties; G) comprising; H) admitted; I) evacuated; J) died; K) before operation; L) after operation; M) comprising; N) total; O) of which; P) awaiting medical aid; Q) subject to evacuation; R) in station; S) with radiation sickness; T) with burns; U) with various traumatic injuries; V) with combined injuries; W) with injuries caused by chemical warfare agents; X) with infectious diseases; Y) total; Z) chief.

In contrast to the OPM, the indications for evacuation to the suburban zone may be considerably narrower here, especially during the initial period. In this case the city hospitals must considerably expand the volume of medical care which they render, taking all measures necessary to ensure hospitalization of the maximum number of casualties, since evacuation during the postoperative period is extremely undesirable.

Having completed his job in the focus of mass injury, the chief of the first-aid station supervises the preparing of medical reports (see illustration) on the movement of casualties over a definite period of time.

The medical classification of radiation casualties during the second stage is conducted principally in the classification and evacuation hospitals and main hospitals and has the following purposes:

a) to locate individuals injured by incorporated radioactive substances and take measures for treating them rationally;

b) to find persons with symptoms of acute radiation sickness so that they may be hospitalized and treated in specialized institutions;

c) to find persons whose clothing or shoes are contaminated with radioactive substances so that they may undergo special sanitary treatment and decontamination;

d) to find persons whose wounds or burns contain radioactive substances and take immediate measures to remove them.

In order to achieve these goals the SEG and main hospitals must have radiometric apparatus, including equipment for detecting radioactive substances in biological media, areas for decontaminating clothing and shoes, separate operating and dressing units, and personnel with instruments for treating wounds and burns contaminated with radioactive substances and for extracting radioactive fragments.

In the admitting and classifying sections of the SEG and main hospitals patients may be divided into those whose skin, clothing, or shoes are contaminated with radioactive substances and must be subjected to sanitary treatment and decontamination and those transportable casualties with incorporated radioactive substances or symptoms of a given form of radiation sickness. This latter group is sent to the hospitals for radiation injuries; untransportable casualties or those in need of immediate medical aid, including those with combined injuries, are hospitalized and treated on the spot.

It may be seen from this scheme for the evacuation of casualties that those with mild injuries are separated at the OPM and surviving

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city hospitals. A large role in the correct assignment of casualties to hospitals is played by the medical assignment stations (MRP) set up on the main highways leading from the city. Traffic from the city carrying casualties or groups of walking wounded with mild acute radiation sickness can be separated at the MRP and directed to the hospitals for the slightly injured for treatment and observation.

When injuries are combined with acute radiation sickness the victims can be sent to hospitals equipped to handle cases of the type corresponding to the injury most dangerous to the organism.

It is convenient to differentiate the casualties in hospitals for radiation injuries into the following groups:

a) persons with incorporated radioactive substances requiring systematic observation and specially trained personnel for their care;

b) persons with a given form of acute radiation sickness;

c) persons with combined injuries (radiation sickness and wounds, burns, fractures, etc.).

Considering that these hospitals must accept casualties with combined injuries, they must have operating and dressing units and wards for casualties with anaerobic infections.

Victims who have been irradiated in doses of 200-300 r or more may later be sent to these hospitals from burn, traumatological, and other specialized hospitals before the third period of acute radiation sickness sets in; at this time the traumas and burns are not dangerous to the organism.

We should note certain problems in the evacuation of patients with radiation sickness. Medical evacuation is that complex of measures intended to remove wound cases and patients in need of treatment from the focus of injury by transporting them to hospitals.

The system for evacuating casualties used by the medical service

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of the GO is based on the principle of "evacuation by destination" which has proved completely justified as used in the military medical service of the Soviet Army.

In essence this principle means that after the casualty is given first aid and classified during the first stage of medical evacuation he is sent to a specialized suburban hospital.

Special hospitals where the necessary personnel, equipment, and medicine can be concentrated must be set up for radiation injuries.

This principle can and must be employed by the medical service of the GO, considering the peculiarities of its work.

The following must be considered peculiarities of the medical evacuation practiced by the GO:

a) the relatively short routes for evacuating casualties, averaging 100-200 km, the routes under field conditions reaching several thousand kilometers;

b) the hospitals used for treating casualties in the medical service of the GO are usually fixed, while under field conditions they are mobile.

While military evacuation usually involves males aged 18-50 years, the medical service of the GO must evacuate casualties which may include a considerable number of women, children, and elderly persons.

In carrying out this two-stage principle of treatment and evacuation by destination, the medical service of the GO must ensure that victims with radiation injuries reach specialized hospitals as rapidly as possible.

One of the peculiarities of the evacuation of casualties with radiation injuries is their relatively good condition during the first and second periods of acute radiation sickness when they have received comparatively small irradiation doses (200-300 r).

The transportation of radiation-sickness patients affects the course of their illness unfavorably and this group of patients should consequently be evacuated during the first and second periods so that they are in the specialized hospitals when the third period of their illness begins.

In addition, it is well known that certain of these victims go into serious condition during the third period,-an unfavorable outcome frequently occurring. Physical stress after irradiation aggravates the course of radiation sickness, shortens the second period, and makes the outcome of the illness worse. It is consequently necessary to set up transportation for such casualties at the OPM when they are classified.

In resolving questions of evacuation-transportation classification, physicians should not proceed merely from the victim's opinion of his own condition, but be guided by the estimated absorbed dose and the character and severity of the symptoms of acute radiation sickness; he should decide the time and place of evacuation, the type of transportation to be used, and the patient's condition. If casualties with radiation sickness are to be evacuated during cold weather, all necessary measures must be taken to prevent chilling; the vehicles and evacuation stations must be furnished with winter blankets, heaters, hot drinks, etc.

The basic principles of medical classification and evacuation given above apply only to atomic (traumatological) foci of injury. The medical classification and evacuation of casualties in bacteriological or chemical foci of injury have their own peculiarities.

Серия Г № 0004

Серия Г № 0004

A Фамилия

B имя

C отчество
Возраст — E

F Адрес

1. Ранение   2 Ожог
3.Закрытое повреждение
4. Кровотечение
5. Отморожение
6. Поражение ОВ
7. Облучение
8. Инфекционное заболе-
вание
9. Другие заболевания
V куда эвакуирован:

Y ——— 196 — г.
   дата заполнения картонки

G H
ч. м.

I дата и час
поражения

J Характер поражения

1. Ранение:
   а) мягких тканей,
   б) с повреждением кости
2. Ожог
3. Закрытое повреждение
   а) кости,
   б) внутренних органов,
   в) контузия
4. Кровотечение
5. Отморожение
6. Поражение ОВ
7. Облучение
8. Инфекционное заболе-
   вание
9. Другие заболевания

W Диагноз и дополнит. сведения о медпомощи

Z Дата и час оказания медпомощи
19 __ г. __ час. ___ мин.

ФАдрес | Серия Г № 0004
фамилия имя, отчество
A B C

K Локализация

N череп,
лицо-
челюсть,
глаза,
шея,
грудь,
живот,
таз,
позвоноч-
ник,
бедро и
крупные
суставы,
конечность:
верхняя
нижняя,

L Медпомощь

O Жгут
   P дата и час наложения

Q Антибиотики
   R доза и дата

S Иммобилизация,
новокаиновая блокада
переливание крови и
заменителей,
антидоты,
сан. обработка

T Сыворотки
а) противостолбнячная
   (доза)
б)

М Эвакуация

U пешком,
сидя,
лежа
в сопро-
вождении

X куда направляется

Фамилия врача
и штамп
учрежд.   AA

A) Surname; B) first name; C) middle name; D) F; E) age; F) address;
G) hr; H) min; I) date and time of injury; J) character of injury; K)
localization; L) medical aid; M) evacuation; N) skull, face and jaw,
eye, neck, chest, abdomen, pelvis, spine, thigh and major joints, ex-
tremities: upper, lower; O) tourniquet; P) date and time of applica-
tion; Q) antibiotics; R) dose and date; S) immobilization, novocaine
blocking, transfusion of blood and blood substitutes; antidotes, sani-
tary treatment; T) sera: a) antitetanus (dose); U) on foot, sitting,
lying, accompanied; V) when evacuated; W) diagnosis and additional in-
formation on medical aid; X) when sent; Y) date when card was filled
out; Z) date and time when medical aid was given; AA) doctor's name
and stamp of hospital. 1) Wound: a) soft-tissue, b) with bone damage;
2) burn; 3) closed injury: a) bone, b) internal organs, c) bruises; 4)
hemorrhaging; 5) frostbite; 6) injuries caused by poisonous substances;
7) irradiation; 8) infectious disease; 9) other illnesses.

A) Physician's special recommendations; B) special notes; C) record of successive stages of evacuation; D) exact diagnosis, designation of stage, and name of classifying doctor; E) date and time; F) arrival; G) departure; H) aid rendered (indicate exactly); I) where sent; J) outcome; K) name of hospital; L) doctor's name.

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